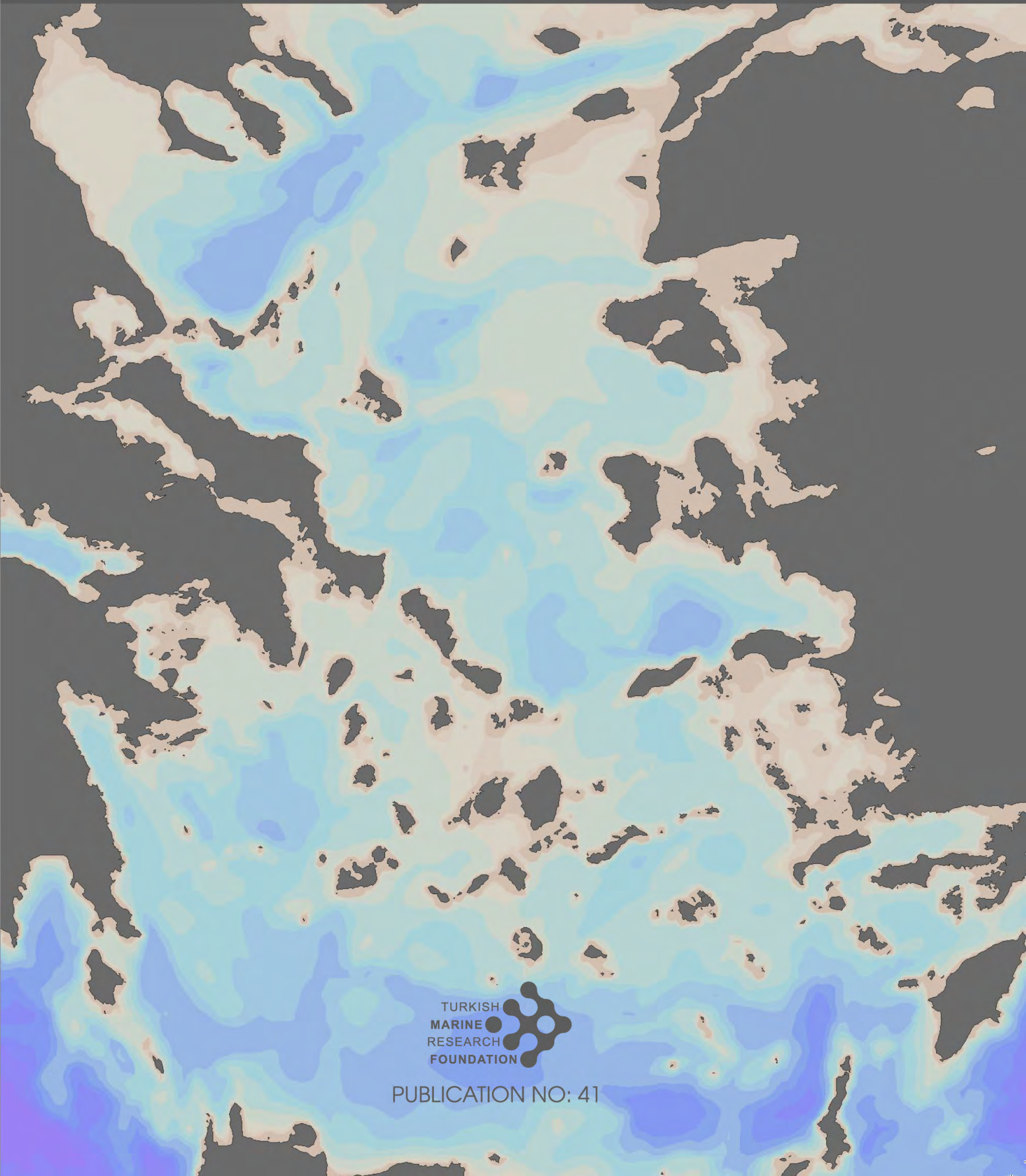
THE AEGEAN SEA

MARINE BIODIVERSITY, FISHERIES, CONSERVATION AND GOVERNANCE

EDITORS: TUNCER KATAĞAN, ADNAN TOKAÇ, ŞÜKRÜ BEŞİKTEPE, BAYRAM ÖZTÜRK



TURKISH MARINE RESEARCH FOUNDATION

PUBLICATION NO: 41

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Publication No: 41

Istanbul 2015

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ISBN-978-975-8825-33-2

Citation: Katağan, T., Tokaç, A., Beşiktepe, Ş., Öztürk, B. (Eds.) (2015). The Aegean Sea Marine Biodiversity, Fisheries, Conservation and Governance. Turkish Marine Research Foundation (TUDAV), Publication No: 41, Istanbul, TURKEY.

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PREFACE

Dear Readers,

The book in your hand now is a collective and combined effort of the Turkish scientists about the Aegean Sea coordinated by the Turkish Marine Research Foundation.

After publishing two important books for the Turkish fisheries, again with the concerted efforts of the Turkish scientists, we are so happy to contribute to deepening of the knowledge about the Aegean Sea. This book will be an important reference book for many subjects mainly concerning the Turkish part of the Aegean Sea.

Besides, we are so pleased to put together experts for various interesting and important topics, such as marine biodiversity, fisheries, pollution, conservation and governance. I'm proud that 75 experts from 16 institutions contributed with 50 papers to this book.

Needless to say, the Aegean Sea has vital importance for Turkey in terms of tourism, living and non-living resources, marine transportation, environment, security etc. This sea has unique charactereristics concerning both marine and terrestial biodiversity. For example, one of the critically endangered species in the world, the Mediterranean monk seal, *Monachus monachus*, lives only in the Turkish and Greek waters in the Mediterranean. Today, the Aegean Sea, however, is suffering from various types of pollution, overfishing, invasion of alien species, and so on. To protect our biological heritages, all stakeholders including scientists and local people should cooperate in every possible way.

We really appreciate all contributors to this book of great variety for the better understanding, conservation and sustainable development of the Aegean Sea. I hope this ouvrage will be a useful source of information for scientiscs, sea lovers, students, NGO's, state administrators and public at large.

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CONTENTS

III. BIODIVERSITY

THE MISSION OF THE AEGEAN SEA
AND RESEARCH VESSEL K. PIRI REIS

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By the mid-1970s, Faculty of Engineering, Aegean University, had created the "Multidisciplinary Research Program for Regional Development" which made the framework of the first effort taken for Izmir Bay in terms of marine research. The University Senate chaired by Prof. Dr. Yusuf Vardar adopted the marine research program by unanimity. As the provision of ship research was needed for data collection at seas, Meat and Fish Authority in the operation of research vessels at that time was contacted for the purpose of ARAR to be given to the projects through to the Ministry of Commerce. However, after a short time, relevant ministries found it appropriate for ARAR to be transferred to the Institute of Hydrobiology, University of Istanbul. Following these developments, in November 1974, the Council of the Faculty of Engineering, Aegean University, made decisions for "Marine Science and Technology" issues for an organization depending on the faculty to conduct research and training and took a very important step with a report that highlights "First of all, personnel and an equipped vessel are needed to make actual marine surveys". A research vessel project was therefore submitted to the Government Planning Organization.

Finally, after the completion of the of R/V K. Piri Reis construction, she was brought to the İzmir Port on 15 November 1978. Institute of Marine Sciences and Technology which was established at Dokuz Eylul University later in 1982, at the beginning of their foundation in 1975 devoted much effort with their administrative and technical staff to the development of marine research.

**He served as Director of the Institute of Marine Sciences and Technology between 1975 and 1993. During these years, he participated in numerous national and international marine surveys and marine projects. He retired from the Institute of Marine Sciences and Technology in 1993.He participated in various marine researches in the Aegean Sea, the Caspian Sea and the Black Sea from 1993 until today.*

While discussing the problems in the Aegean Sea, the institute organized the first national meeting titled "Sea Problems of Turkey and Maritime Law Seminar" on 1-4 March 1976 in Izmir. This meeting brought the attention of Turkey to marine issues.

Starting in 1982, the first important series of follow-up studies were conducted up to the end of 1985 by the research vessel K. Piri Reis. Apart from the work done under the MED-POL Phase II involving 12 countries, including Turkey, studies were carried out by the European Union EUROMAR Project, the formation of which took place in London in 1986.

In the 1980s, in order to safeguard Turkey's maritime rights and interests, serious problems were found with the neighboring country of Greece. Thus R/V K. Piri Reis worked in the international waters between Greece and Turkey. This sea is effected by the Eastern Mediterranean in south and by the Black Sea area in north. The effects of the chemical characteristics of the sea water and changing salinity as well as current effects are important. Very critical moments in terms of security were experienced in those days and our research vessel also lived "difficult years" in the international waters

EUREKA was created in July 1985, and the agreement was signed by all members in London in June 1986. So far, the members include 19 European countries and the commission of the 12 Committee member states, 6 European Free Trade Association (EFTA) countries and Turkey. The EUREKA Project EU 37 EUROMAR was officially announced at the 3rd Ministerial Conference on 30 June 1986, London.

EUROMAR was established in 1986 with the major goal of enhancing the co-operation in research and production of advanced marine technologies. Prof. Dr. E.K. Duursma (The Netherland) was the chairman of the EUROMAR Board.

Satisfactory marine research results were obtained with this international cooperation Turkey and other countries under EUREKA and EUROMAR. An oral presentation was made at the 13th CIESM Congress in Palma de Mallorca, 1986, titled "10 years (1975-85) of the Institute of Marine Sciences and Technology" and the ship information and survey information were distributed to the participants. Additionally, in 10 years, many reports of marine constructions of facilities, natural gas pipelines and marine surveys at different harbors and technical facilities were realized.

Later R/V K. Piri Reis became fully equipped to fulfill her task adequately in the Aegean Sea. The many materials of marine studies of various universities participated in numerous academic studies in serving science people are provided with K. Piri Reis.

In about 3 years later from today, K. Piri Reis will be forty years old, technological innovations will be updated accordingly and she will continue her activities.

Greece did not have a research vessel. In this regard, the studies made with K. Piri Reis were followed closely at each stations which were declared so by CIESM, EUROMAR and some other important joint survey initiatives. (Note: This you may find also under the “Pollution in the Aegean Sea”). Finally, in the late 1980s, our neighbor country Greece has also their own survey vessel.

I participated at a glorious conference “EUROPE AND THE SEA” held in Hamburg in 1988. First our discussion was accompanied by Professor Dr. H.U. Roll, Honorary Chairman (German Committee for Marine Sciences and Technology). Then, I had a chance to discuss with Prof. Dr.-İng. K. Kokkinowrachos, Chairman of DKMM (German Committee for Marine Sciences and Technology) and Prof. Dr. J. Makris, Institute for Geophysics, University of Hamburg. These two scientists supported me enthusiastically for the continuous marine studies in the Aegean Sea during the meeting in Hamburg.

River outputs from the Anatolian border shore areas are extraordinary important for the eastern part of Aegean Sea. At the end of the above meeting, Prof. Dr.-İng. K. Kokkinowrachos and Prof. Dr. J. Makris supported me and the Turkish research vessel K. Piri Reis activities for very valuable data. The chemical and physical conditions of seawater in the eastern part of the Aegean Sea need to be understood clearly. R/V K. Piri Reis investigates the entire sea as far as Crete in south. Seasonal transportation has been made from the Anatolian coastal area to the Aegean Sea but also more detailed data are essential.

Although Greece is officially in the European Community, in anticipation in the coming days, we will work together again with R/V K. Piri Reis owned by Institute of Marine Sciences and Technology in Izmir in the environment of peace. I believe that we will work together for strengthen the peace in marine environment.

I think that by working hard to pursue ambitious objectives, successful work can be done on the living and non-living resources, which are coming from the land of both countries, then entering to the Aegean Sea as well as from the input and the output of the Black Sea and Mediterranean Sea to the Aegean Sea.

The General view of the Research Vessel K. Piri Reis after three years of intensive marine research and surveys in the Aegean Sea (1982-1985)

AEGEAN ISLANDS BY THE VISION OF PİRİ REİS

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1. Introduction

In his work named “Bahriye”, Piri Reis didn’t ignore to indicate the relevance of the islands of the Archipelago with the neighboring islands and the coasts of the mainlands as he saw with his own eyes and with diagrams of the subjects in map formats.

As it will be seen from my study; no researches and studies were made either domestically or abroad until the present day. The relevance of the islands with each other and the coasts of the mainlands, the groups formed by minor islands situated in wide marine spaces intervening in some geographical regions are indicated with small dots and hollow geometrical figures on the diagrams in map formats within the related subjects. Piri Reis didn’t mention about these groups because of the uselessness of them. However, he showed them in the diagrams particularly in order to provide the integrity of the region and to point out the sailing dangers created by them. They don’t have specific names. Because of these and suchlike reasons, readers and researchers looking at these diagrams of the “Bahriye” couldn’t understand what these islands are, this originates from their unawareness of the style of Piri Reis. Consequently, they couldn’t make any comments. Firstly, we must remember and keep in mind that all the data of this book were compiled and written in order to make it understandable for everyone.

The locations of these minor islands and reefs adjacent to the islands, indicated by dots and hollow geometrical figures are 25-50 miles away from the relevant island or islands. In this study, I am explaining the style of Piri Reis and help to expound the esoteric shapes of the Archipelago islands which could not be understood. Because of their interestingness, I took the islands of İncirli (Niseros), Değirmenlik (Milo-Milos) and Yavuzca (Sifnos) as examples for supplying information in my study. Additionally, I mentioned also thir views from distant angles according to the sailing approach to large and small islands. I saw and visited all the islands in situ in my 12 year-long sails in the Mediterranean for my researches and examinations on “Bahriye”.

1.1. Piri Reis and Aegean Islands

Taking advantage of the sources he obtained from his observations, researches and surveying of a period of 25 years, Piri Reis prepared a book principally for himself, compiling all the coasts of today's Mediterranean Sea also including both Adriatic Sea and Aegean Sea (the Sea of the Islands, the Archipelago). Expression of the Archipelago in this magnificent work has a significant peculiarity and value and he discoursed this aspect referring to he activities of the navy and the marines as ".... It is necessary to learn the Western Seas / So this is why I mention all these / And I named it as BAHRİYYE ..." (Senemoğlu, 1973).

The authentic book Bahriye by Piri Reis begins with the chapter dealing with the Dardanelles of the present day which was known as the Mediterranean Strait in the 16th century and the two oppositely located fortresses of it, namely Kilit Bahr (the lock of the sea) and Kale-i Sultaniye (constructed by the order of the Sultan; Çimenlik Fortress – Çanakkale). This is not a random preference, but the result of a clever thinking. It has an obvious reason. Because the Ottoman Navy departs from the docks of Haliç (the Golden Horn) for the annual campaign and attends the ceremony in front of the Yalı Kiosk in order to salute the Sultan and receive his consent and benison and then set sail and arrive at the Sanjak (district) of Gelibolu (Gallipoli). Following the replenishment in this port, the navy goes to Sultaniye Fort for water supply. Thus the last preparations of the navy to sail from the Mediterranean Strait to the Archipelago was completed in these fortresses. This is why the first page of the Bahriye Book begins with defining these fortresses and goes on with the explanation of the islands in situated in front of the strait.

Because our subject is about the marine geography of the 16th century, the name Sea of the Islands which we inherit from our ancestors will be used instead of the Aegean Sea.

The most essential issue considered while organizing the Sea of the Islands of Bahriye is primarily the coasts of the two mainlands and the islands nearer to the coasts were explained before the other ones. The explanation of the islands located in the center of the South Sea of the Islands were grouped afterwards and discussed within a different system. As it will be seen below, 35 islands and island groups were approached in the front chapters and other 15 islands and holmes were handled in the last part of the book; this depends upon the peculiarity of the Sea of the Islands.

In his book Bahriye, Piri Reis discourses the most important 50 islands of the Sea of the Islands. As a matter of fact, the number of the islands is more than it is shown here; many of the islands mentioned in Bahriye were discoursed as groups, for example Hurşit and Foroz Islands (İkaria and Fuorni Islands), Karoanti and Karo

Islands (Ano Antikeri and Keros Islands), Çamlıca and Boz Ada (Khelidromi and Piristeri Islands). Because islands such as these were explained in one chapter, it seems that there are only 50 islands. In the diagrams of the topics in map formats and with the exception of the large neighboring islands near the subject island, dots and some nameless but important holmes drawn and painted in various forms, rubbles and some shallow rocks were not defined but they were shown in the relevant map figures in order to maintain the entireness of the region.

The islands explained by Piri Reis in Bahriye were organized in the book within two groups. The first group comprises the neighboring islands in front of the coastline of the Western coasts of Anatolia and islands such as Eğriboz Island near the Eastern coast of the Attica Peninsula of Greece. These islands as per the ordonnance of Bahriye are respectively; Bozca Ada, İmroz Island, Semadirek Island, Ilımlı Island, Taşoz Island, Ağrıboz Island, Midilli Island, Sakıs Island, Ipsara Island, Sisam Island, Islands of Keçi and Bulamaç, Himaran Islands, Hurşit and Fornos Islands, Kerpe Island, Patnos Papaz Island, İleryo Island, Kelemez Island, Keçi Island, İstanköy Island, Sömbeki Island, Rodos Island, Harke Island, İlâki Island, İncirli Island, Koç Baba Island, Yamorki Island, Kara anti and Karo Islands, Nakşa Island, Bara Island, Sire Island, Sığırcıklar Islands, Munke Island, İstendin Island, Andire Island and Cuha Island. Second group of the islands form the last subjects of Bahriyye and they are respectively; Kerpe Island, Girit Island, Anafya Island, Santoron Island, Anye Island, Polikandire and Si Kandire Islands, Değirmenlik Island, Yavuzca Island, Koyunluca Island, Terme Island, Mürtad Island, İskiri Island, Iskados and Iskabolos Islands, Çamlıca and Boz Islands, Keçi Island.

While Piri Reis was organizing these islands as per his own system, he took into consideration the distances between the islands, the groups formed by these convergences and the spaces of thirty and sixty nautical miles between them without ignoring the holmes and rock rubbles dangerous for the ships and indicated them in map formats of the subject. Because he placed them right in the correct point with their relations with the neighboring islands and with the method of comparing their geographical locations. All these diagrams were drawn by observing them in situ. The interesting aspect of these diagrams is that the style he used in order to understand and scrutinize them is known. Because he was sure about the exact placing of these sailing risks, he discoursed always and especially at the end of fifteen different chapters as a warning such as 'refer to the diagram or diagrams when necessary'; for example original copy of Bahriye folio 81/b; "... the harbor of Çeşme is a good place for mooring... however, the aforesaid harbor has two large shallow points with a little distance from its opening, attention must be paid to these ...in order to understand them better one must refer to the relevant diagram when needed..."

The subject islands discoursed here are seen with interesting appearances when they are in sight during the approach of the ship of the observer. The role of these interesting forms is important for the sailors to constitute their positions. Because these interesting appearances of the islands, holmes and rocks seen at the first glance will change by approaching them. The first example for the holmes and rocks having interesting forms and met within the horizon distance sight in the sailing area is at the Northwest tip of the Karabağ peninsula of the Southwest coast of Anatolia. Sıravolos Coasts according to Bahriye and with a position of 2.5 nautical miles Northeast of today's Yalı Kavak Bay, it is a black floating rock 60 centimeters above sea level and situated on the sailing route. The name of this rock on the British Admiralty map of the region is Wreck Rock and it is registered as Gemi Taşı on the Turkish Marine map of the region. This rock seems like a small ship on the horizon during the approach from North or South to Yalı Kavak and Gümüşlük Harbors in open and clear weathers. Piri Reis explained this rock in Bahriye's "Explaining the Sıravolos Coasts" chapter as "... at the tip of the bow... it is the Palamut Bökü Harbor. There is a sharp rock opposite this harbor and it looks like a sail when looked from the sea..." (Senemoğlu, 1973).

For the understanding of the book Bahriye, it is necessary to see the geographical places of the subjects in situ or refer to the marine maps of the British Admiralty related to these regions and prepared at least half a century ago with very delicate measurement and fathom system, without these it is impossible to understand this sea. On the other hand, it is not possible to understand the entire work without having the subculture on the data of 16th century chart drawing rules of the diagrams of the map format about the topics of Bahriye. Mentioned below are a few examples chosen from a lot of proofs on this matter.

1.1.1 İncirli (Nisiros) Island

Figure 1: Incirli (Nisiros) Island

The map format diagram depicting the chapter İncirli (Nisiros) Island as it is named in Bahriye situated offshore Southwestern Anatolian coast. We must pay attention to the shape of this map format diagram before examining the subject. The arrow of the compass rose showing North on top of the diagram was marked with mistake. The correct North tip must be slided 45o to the direction on right. Thus, the ruins of the İncirli Fortress (I visited them in situ) on top of the cape on correct geographical position Northwest of the island will be placed on the correct position. Piri Reis mentioned the town on the high cape formed by the mountain fragment leaning towards the sea as "... it is also called Mendiraki...". The present name of the town is still the same. When the diagram with map format is carefully examined, it will be seen that the fortress of the island, the islets near the coast depicted by three small dots, other islands and rocks away from them are not on their real positions because of the mistaken North direction, but on the Northeastern position.

If the arrow showing the North will be placed on the tip of the other line of direction at 45o, all the islands, islets and rock rubbles will return to their real positions and placed at at Southwest of İncirli (Nisiros) Island. Although the total of seven islands, islets and rocks which were placed mistakenly on the Northeast of the island and shown near the West coast of İncirli Island, in fact they are Sirene Nisis island groups or with the present name Agios Ioannis Islets situated 25 nautical miles Southwest of the island.

1.1.2 Nakşa (Naksos) Island

Figure 2: Nakşa (Naksos) Island

In the Nakşa (Naksos) Island chapter of Bahriye, Piri Reis didn't mention about a group of eight large and small, infertile and rocky, useless islands and islets situated from Northeast to 11 nautical miles to Southwest and positioned in front of the Southeast coast of the island. But in order to maintain the entireness of the region, he showed them by drawing them in a row, without indicating their names, with their exact geographical positions and depicting that they are 2.5 nautical miles from Southeast coast of Nakşa Island.

According to what is told in the subject of Hacılar Island or Tenose Island which is the largest one; these islands are from right to left after this large one are the ones their names not given and they are respectively Kuphos Island, Agrilos Island, Ophilusa Island, Heraklia Island, first island at the right row, Karos Island, Anti Karos Island and Islet of Pelatiha.

In the preface of Bahriye, Piri Reis explains the reason of his drawing of these nameles islands respectively in the part "States the Signs of the Map" as "... if the small islets are obvious / their numbers will be written to be known..." (Senemoğlu, 1973).

1.1. 3 Değirmenlik (Milo-Milos) Island

In Bahriye, there is a large space of open sea between Değirmenlik (Milo-Milos) Island and at the West of the coasts of Yavuzca (Sifnos) Island which is 27 nautical miles Southeast of this island and the East coast of Mora Peninsula which is 75 nautical miles away from them. This region is an important region where the merchandise routes used intensively by the ships passing from today's Dardanelles towards the Sea of the Islands and sailing to the ports of Western Mediterranean, Europe and Africa and coming from these ports and going to İstanbul and ports of the Black Sea via Dardanelles. In the center of this region, near to each other, there is the Phalconera Island (elevation: 183 m. – 600 ft.), 40 nautical miles Northeast of Cape Maleas which is the Southeast tip of Mora Peninsula within a circle with a diameter of approximately 22 nautical miles, at the Eastern tip of the diameter of the circle and the Islet of Parapola (Belopoulo-Belo Pulo) (elevation: 213.5 m. – 700 ft.) at the Western tip of this diameter.

There are Karavi Rocks on the Southern bow of the circle drawn with this diameter, 10.5 nautical miles distant from Parapola Island, it is impossible to reach their peak with 33.5 meter elevation from the sea level. They look like a sail boat from a certain distance.

The area of the geographical region of these rocks and rubble islets which create an important sailing risk is approximately 190 square miles. The ship coming from West and turning to Northeast enters the Sea of the Islands by a cape, the Southeastern cape of the Mora Peninsula on the Sea of the Islands; the name of this cape in time of Piri Reis was Kav Malio, Turkish sailors call it Benfeşe or Temaşalık Cape, the name on the charts of the time was Santa Antonio. The ship which passes by the Karavi Rocks, the first rock rubbles 28 nautical miles Northeast of this cape, passes from the East of Belo Polu Island which is 10.5 nautical miles Northwest of these rock rubbles. At this moment, Belo Polu rocks look like an egg divided into two. This appearance changes by the approach to the rocks. There isn't any appropriate route for going to Dardanelles from this cape and for the ships which go downwards to South to go from Dardanelles to Maleas Cape. This is the reason of the intensity of the ship traffic on this route.

When discoursing Değirmenlik (Milo-Milos) Island, Piri Reis didn't mention these three dangerous rocks. However, because Phalconera Island which is 17 nautical miles from Değirmenlik Island and Karavi Rocks which is 14 nautical miles Southwest of this island can be seen with a careful observation under open and clear weather confitions, they have been shown peculiarly with the name Yeksimade in the map format diagram of the chapter. The reason why he showed these islets near the island on map diagram, is that the ships entering the Sea of the Islands by bassing the Meleas Cape on the Southeast tip of Mora Peninsula, will see the Karavi Rocks which are 28 nautical miles from this cape either they use the Northeast or the East route. Naturally, ships following the East route on their way to Değirmenlik (Milo-Milos) Island and Cyclades Islands by passing the Meleas Cape of Mora Peninsula will see the Karavi Rocks and Phalconare Island from a distance of 12-14 nautical miles. When these ships follow the West route on their return voyage or come downwards from Northeast to Southwest by Southwest route, they will encounter the same condition.

If Piri Reis wouldn't show these islands, a marine region approximately 75 nautical miles wide and 85 nautical miles long to the channel opening of Zea or Kea Island which is the second important channel after Maleas Cape, totalling approximately to 6375 square mile between Milos Island and Eastern coasts of Mora Peninsula will be empty and he would not be able to maintain the entireness of this geography between Milos Island and the East coasts of Mora Peninsula. This is an essential detail.

According to my personal opinion, Piri Reis, who considered the connections of the marine spaces in between the islands and the coasts of mainlands, created a base for the discoursing of the region in the book published by British Admiralty previously with the name Sailing Instructions and named afterwards as Mediterranean Pilot Vol. IV, 1882-1968, the part depicting the Sea of the Islands.

When the map format diagram of Piri Reis depicting Değirmenlik (Milo-Milos) island is examined carefully, it will be seen that there is a group of rock rubbles formed by floating rocks circling a small holme at the Southwest direction of the island. Piri Reis wrote their name as İhtanye on these rock rubbles. He drew this group comprising seven rocks circling a useless and dangerous elevated rock deliberately because of the sailing risk. Piri Reis didn't mention about these rocks in the text of the related chapter but because of the above explained condition, owing to the entireness of the geographical region and according to its importance he showed these rocks on the map format diagram.

These rubble rocks are located 236o1⁄4 direction and 10 nautical miles off Psalis Cape, the Southwestern tip of Değirmenlik (Milo-Milos) Island. It is a very dangerous rocky group for ships and composed of one big, four medium-sized and two tiny dark black colored rocks.

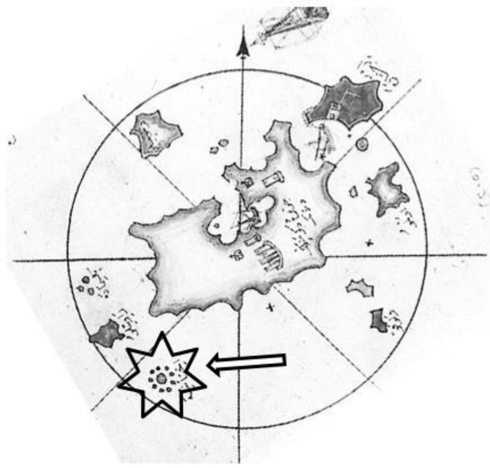

Figure 3: Değirmenlik (Milo-Milos) Island

When an approach to North with 012o route is followed, the seven small rock rubbles circling the large island with its peak point with an elevation of 46 meters are seen from a distance of seven nautical miles. The largest island is just near the two rocks situated South of these rock rubbles and the four medium-sized rocks are on the North of them forming a bow of 0.6 nautical miles (1110 m.) long. When I was sailing in these waters with the purpose of examining Bahriye, Piri Reis had to see these strange nature rocks as I have seen them on the spot. These rocks ascend from the seabed to the surface vertically. They have needle sharp edges and look like the teeth of a carpenter's saw. Narrow and shallow waters with a depth of 10 meters encircle these rocks with an oval frame and their new name is Anenas. The depth goes down suddenly to 50 meters and then to 100 meters as a high cliff. In calm weathers, there are currents with a force of 11⁄2 knot around these rocks and they are dangerous. This is why it is recommended to the ships sailing in these waters to steer off. Piri Reis, who saw these realities in situ, drew Değirmenlik (Milo-Milos) Island in map format with these seven rock rubbles encircling it. This detailed explanation is for a better understanding of the map format diagrams that they were drawn for Piri Reis himself and his uncle Kemal Reis.

There is another issue to be explained herewith. While using some special marks for defining the islands, Piri Reis drew the map format diagrams with the shapes of the mountains and hills of the islands as they are seen from a distance away. Additionally, he drew mountains and hills behind the coasts of the mainland parts surrounding the Sea of the Islands, with his vision and for knowing the coast to be approached. This aspect was not noticed until today even by the researchers.

One of the best examples of this matter in Bahriye is the map format diagram depicting the Port of Saplıca and Alaçatı at coasts of Western Anatolia.

In this diagram with map format, Port of Saplıca is the second port from left (West) to right (East). Behind this port, in the inner parts of the mainland and on the Northeast (northeast wind) direction, the upper part of a high hill was coloured blue in the authentic work and looks like as if added there afterwards in order to attract the attention and a note explaining the importance of this hill was added near it.

Piri Reis writes the text of the authentic explanation as “the mark of Saplıca is a sharp edged rock and looks like a citadel tower from a distance” and gives the information “... when there is a distance of beş six miles from the sea you sea a mountain on the land. The rocks on this hilltop look like a ruined fortress. An islet will come into sight during the approach to here...” and he made a warning by defining the approach to the port by a maneuver to pass the islets at the opening of the port.

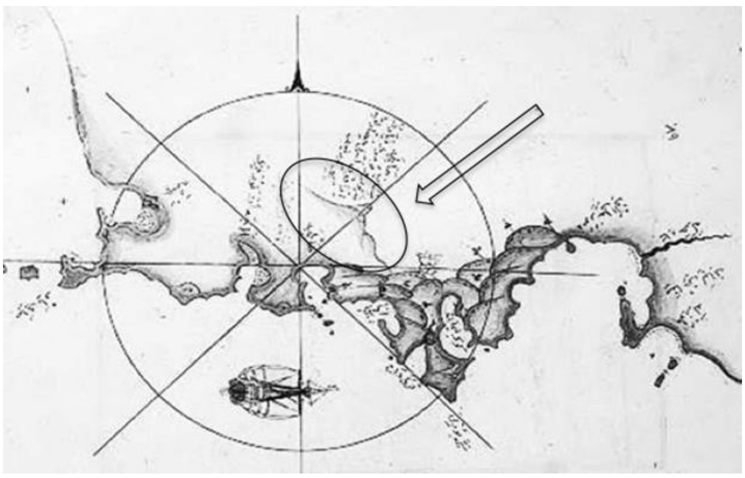

Figure 4: Port of Saplıca and Alaçatı

While approaching the Port of Saplıca by Southwest routes, the opening of the port looks like closed because of a group of holmes which are called Dümbelek Islands today. When sailed towards the hill which looks like a citadel tower according to Piri Reis and came a nautical mile near the land, the opening starts to become visible. I experienced this sail personally and witnessed the correctness of the information (Senemoğlu, 1973).

Figure 5. Selections of photographs I have made in 1988 while driving towards İzmir on Çeşme – İzmir motorway as marked by Piri Reis for the Port of Saplıca

Figure 6. An older sketch of the hill drawn by me.

Another example is about Bozca Ada. While explaining the island in the relevant issue Piri Reis makes an emulation as “... Low and infertile place. There are a few grey hills on its highest grounds on the North. When looked from these hills, ships which are 40 miles away can be seen. The ones looking from the sea see this hill as a tent from 30 miles. This hill is the sign of the island...” (Senemoğlu, 1973).

The subject about Eğriboz or Ağrıboz Island is another example. The noticing of this island from a distance is told by Piri Reis as “... Its sign while coming from the sea is a sharp tipped mountain among other mountains. This mountain is visible from Midilli Island. It is 100 miles from Midilli to Ağrıboz...” (Senemoğlu, 1973).

The last example is from Kelemez (Kalimnos) Island; Piri Reis explains this island as “... This bay is called Sikadin (today’s Port of Palaio)... This port is a mountain which looks like an island from a distance. On this Kelemez, there are Kelemez Mountains. They reach to a point which looks like an island. They take this island-like structure to their left and enter inside...” (Senemoğlu, 1973).

2. Conclusions

I made surveying expeditions in the Mediterranean with its present day name, by taking the magnificent work Bahriye (St. Sophia copy, No. 2612) of Piri Reis as a guide for 12 years; there are many more issues by Piri Reis which because and under the light of the experiences I acquired during these voyages, I admired the marine geography knowledge, style, logic and professional perspective and talent of appraisal of Piri Reis and also astonished many times. Finally, I understood that being in the sea is obligatory in order to understand this work and one must think and act as the captains of the 16th century.

These are the most important specialities of the book Bahriye. Piri Reis didn’t show only the solid islands, but also the numerous holmes and rocks by knowing and deliberately in his diagrams in order to maintain the geographical entireness of the region.

I memorise this great sailor with mercy and gratitude and conclude with his saying.

“That’s the thing”.

Reference

Senemoğlu, Y. 1973. Kitab-ı Bahriye (Denizcilik Kitabı), Tercüman 1001 Eser, Kervan Kitapçılık A.Ş.

THE AEGEAN SEA WITH NUMBERS

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1. Introduction

The Aegean Sea has equal strategic, economic and political importance for neighbouring two states, Turkey and Greece. Therefore determining the baseline and the maritime line around the Aegean Sea between Greece and Turkey and the line, from which the outer limits of the State's territorial sea are measured, have been discussed and interpreted for years between those countries. In this study, the Landsat MSS satellite imagery is used in order to produce a digital vector map covered this area. Because, remotely sensed multispectral data collected from satellites provide a systematic, synoptic ability to assess conditions over large areas on a regular basis (Jakubauskas and Price, 1997). Geometric reprocessing of the Landsat MSS images was performed using ERDAS Imagine 8.2 software. All images were geometrically corrected by using 1:50 000 scale topographic maps. Rectified images have been used to create an image mosaic.

According to NATO standards Turkey and Greece produce their national map sheets in Universal Transverse Mercator (UTM) System. Therefore the reference coordinate system is selected as UTM for the rectification process. On screen digitised vector data are created first UTM zone 35 ($\lambda_0 = 27°$) that is used for mapping the regions of Turkey. The same data are transformed then to zone 34 ($\lambda_0 = 21°$), which is used for mapping the Greek region. The data is also transformed to a non-standard zone ($\lambda_0 = 25°$), which covers the study area. The length of the coastline belongs two countries has been evaluated according to the three central meridian mentioned above. The water area of Aegean Sea has also been computed. All digitised data was transformed into an equal-area projection surface. On this surface, the total water area of the sea was computed. Finally, true length and area values have been obtained and presented.

2. The Boundaries of the Aegean Sea

The Aegean Sea is surrounded by the western coasts of Anatolia from the east, the southern coasts of Thrace and Eastern Macedonia from the north, the eastern coasts of Thessaly and Peloponnese peninsula from the west and the islands of Crete and Rhodes from the south. It covers an area of 191,000 km^2 approximately.

There is no unique definition on the southern boundary of Aegean Sea. For this study some of the definitions from encyclopedic sources are interpreted (Ana Britannica, 1994), International Hydrographic Bureau (SP23, 1953), and national atlases (Atlas, 1993). Using all these sources, a boundary, especially in the southern region of Aegean Sea, may be suggested which can be commonly accepted. This non-natural boundary has to have some characteristics as natural boundary. The deep trough situated to the south of Crete, Karpotos and Rhodes islands, is the surface indication of a major feature, which cuts across the whole lithosphere. This through is a principal element of a plate boundary. It could be either a trench (Makris 1978; Le Pichon and Angelier, 1981; Makris and Stobbe, 1984; Spakman *et al.*, 1988) or a fore-arc (Hellenic) basin (Le Pichon *et al*.,1982) in "plate tectonics terminology". A boundary for the Aegean Sea is defined under these decisions with geographic locations shown in Figure-1 (Goksel *et al.* 1999, Goksel *et al.* 2001).

3. Methods and Application

The satellite images used here are Landsat-MSS Images, with 80m spatial resolution. The MSS scene is defined as an image representing a ground area approximately 185km in the east-west direction and 178km in the north-south direction. The MSS scene is an array of pixel values (in each of four bands) consisting of about 2400 scan lines, each composed of 3240 pixel. There is a small overlap about %5 between scenes in the path to the north and south. The side overlap to the east and west depends on the latitude. It can be said that there is an approximately %30 sidelap near the 40° latitude (Campbell, 1996).

A series of image frames has been joined to form a mosaic. This mosaic is covered spatially by 17 Landsat MSS images. All imagery was collected from July to September 1993. 1:50000 scaled standard topographic maps are used for rectification process. The study area covered by 17 frames includes approximately 115 map sheets. In this study 91 of them are used for selecting ground control points.

Figure 1. The boundaries of Aegean Sea

Totally 279 ground control points are selected on the 1:50 000 scale maps and they used for the rectification map to image. Approximately 100 control points are also used for image to image rectification. So it can be said that approximately 20 control points was used for each frame. The 1:50 000 scale topographic maps belong to the Turkey are produced in the UTM projection system, zone 35. The Greek maps are produced in the same projection system, but in a different zone (zone 34). The coordinates of ground control points which lies in UTM zone 34 are transformed to the UTM zone 35 (Goksel *et al.* 1999). Positional accuracy of satellite images generally means the degree of accuracy of an image corrected geometrically. Correction, in this sense, contains a register into a reference coordinate system with a resampling method (Irish, 1990; Jansen and Van der Well, 1994; Goksel, 1998). First order polynomial rectification method and nearest-neighbour resampling method are used in this process. A total root mean square (RMS) error between 0.35 and 0.55 pixels is reached for each of the images. ERDAS Imagine 8.2 version is used a mosaic of Aegean Sea has been prepared, which is shown in Figure 2 (Goksel *et al.*, 1999).

The natural coastal line belongs two countries has been digitised using this mosaic with on screen digitising method. The digitised coastal line has been examined in respect of digitising errors like undershoots, overshoots etc. After some corrections, lines are enhanced so that they are topologically consistent.

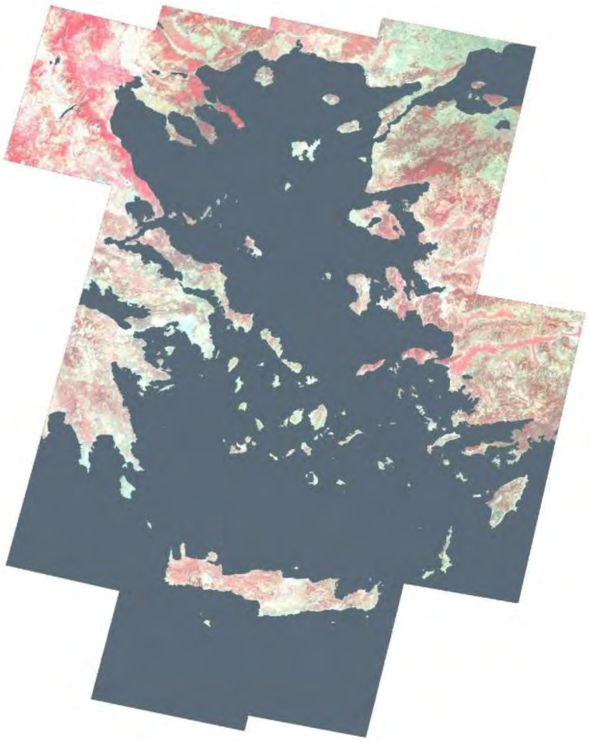

Figure 2. The mosaicked Landsat MSS image of the Aegean Sea

Six layers for classification of the lines are generated as COAST_TURK (coastal line of Turkey), ISLAND_GREEK (islands belong to Greece), ISLAND_TURK (islands belong to Turkey), COAST_GREEK (coastal line of Greece), CONNECTION *LINE* (the southern extremity of Aegean basin in water region) and ISLANDGREEK_MIX (the northern coastal lines of the Greek islands on the southern part of the Aegean Sea). Name and description of those layers are listed in Table-1 and the digitised vector data are represented in Figure 3.

Table 1. Name and description of the layers

Layer	Description
COAST_TURK	Coastal line of Turkey
ISLAND_GREEK	Islands belong to Greece
ISLAND_TURK	Islands belong to Turkey
COAST_GREEK	Coastal line of Greece
CONNECTION_LINE	The southern extremity of Aegean basin in water region
ISLAND_GREEK_MIX	The northern coastal lines of the Greek islands on the southern part of the Aegean Sea

Figure 3. Digitised data

For each category the lengths and areas have been calculated (Goksel *et al.* 1999). These categories and related results of the first part of the study are shown in Table-2.

Table 2. The lengths and area for each category (km^2/km)

	Turkey	Greece	Aegean Sea
Number of islands and rocks	96	460	556
Total area of islands and rocks	427,29	12613,04	13040,33
Total perimeter of islands and rocks	470,02	6792,96	7262,98
Length of natural coastal line of partial Aegean islands (Kithira, Crete, Karpatos and Rhodes)	0,00	948,72	948,72
Length of natural coastal line without islands	2327,81	2732,04	5059,85
Length of natural coastal line with islands	2797,83	10473,72	13271,55
Total water area	--	--	193950,33
Total perimeter of the sea	--	--	6337,14

4. Distance and Area Comparisions

Using the digitised data, the lengths of coastal lines belong to Turkey and Greece respectively and the area of the Aegean basin are calculated and compared under different cartographic assumptions in order to analyse the differences obtained from different reference parameters.

Aegean Sea takes place in the UTM zones with the numbers 34 and 35. The central meridians of these zones are λ_o=21° and λ_o=27° respectively. The digitised coordinates are the UTM coordinates according to the central meridian λ_o=27° East. The ellipsoidal longitudes and latitudes are then computed from these UTM plane coordinates using inverse solution. Using this geographical data the UTM coordinates are computed according to the central meridian λ_o=21° and to a non-standard meridian λ_o=25° which goes through the middle of the Aegean Sea. The length of the geodesic for each segment between the consecutive points is calculated using the ellipsoidal coordinates (Pearson 1990; Maling 1992; Leick 1995).

In UTM system, distortions increase away from the central meridian. The effect of such distortions causes wrong comments during discussions about the length of the coastal lines. Turkey is approximately 200km far away from the 21°meridian. Greece is approximately 275km far away from the 27° meridian. Because of these reasons calculations are made in two zones 35 and 34 respectively. The lengths of the lines for each layer are computed for those two zones and compared with the lengths of geodesic, e.g. the true lengths on the reference ellipsoid. As a suggestion a non-standard central meridian is chosen as 25° which go through the middle of the study area. The calculations are repeated for this non-standard zone. The results are presented in Table-3. The differences of the lengths from the true lengths of geodesic are presented in Table-4 (Goksel *et al.* 2001).

As can be seen the differences in Table-4, if the central meridian of 21° is selected, the length of the coastal line of Turkey is calculated approx. 7.6km long as it should be. Oppositely, if the central meridian of 27° is selected, the length of the coastal line of Greece is calculated approx. 2.2km long as it really should be.

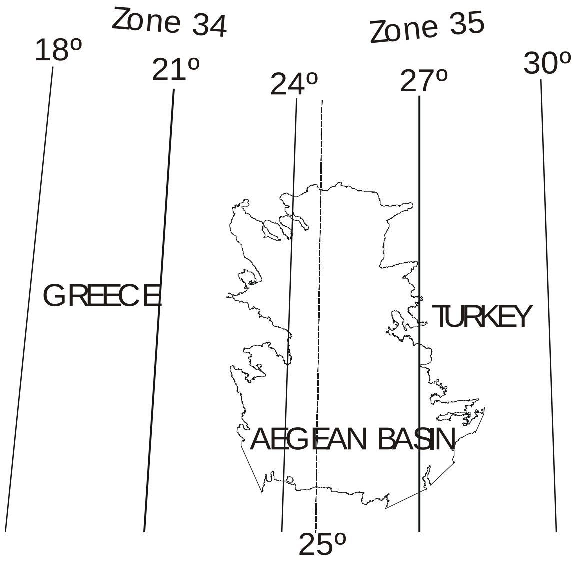

Figure 4. The meridian interval covers Aegean Basin

Table 3: The lengths computed from UTM coordinates using different central meridian (m)

Layer	Length of Geodesic	λ_o=21° (ZONE 34)	λ_o=25° (non-standard)	λ_o=27° (ZONE 35)
COAST_TURK	2328640.455	2336191.443	2328832.937	2327807.118
ISLAND_GREEK	6792776.086	6803017.685	6791117.209	6792962.766
ISLAND_TURK	470182.299	471460.468	470147.977	470018.038
COAST_GREEK	2729884.068	2730438.442	2729492.849	2732040.255
CONNECTION_LINE	328529.493	329335.863	328561.787	328573.026
ISLAND_GREEK_MIX	948645.503	950425.984	948517.200	948719.539
AEGEAN BASIN	6335699.507	6346391.719	6335404.761	6337139.938

Table 4. The differences from the length of geodesic (m)

Layer	λ_o=21°	λ_o=25°	λ_o=27°
COAST_TURK	7550.988	192.482	-833.337
ISLAND_GREEK	10241.599	-1658.877	186.68
ISLAND_TURK	1278.169	-34.322	-164.261
COAST_GREEK	554.374	-391.219	2156.187
CONNECTION_LINE	806.370	32.294	43.533
ISLAND_GREEK_MIX	1780.481	-128.303	74.036
AEGEAN BASIN	10692.212	-294.746	1440.431

During distance calculations with the UTM coordinates it is suggested that if the distance reduction adds to the coordinates the computed distance has closed to the distance on the ellipsoid (Leick 1995). Therefore all of the calculations are repeated using these reductions for each central meridian mentioned above. The results are presented in Table-5. The differences of the lengths computed with reductions are also compared with the lengths of geodesic and the results are presented in Table -6 (Goksel *et al.* 2001).

Table 5. The lengths computed from UTM coordinates with distance reduction (m)

Layer	Length of Geodesic	λ_o=21° (ZONE 34)	λ_o=25° (non-standard)	λ_o=27° (ZONE 35)
COAST_TURK	2328640.455	2328173.628	2328200.100	2328201.213
ISLAND_GREEK	6792776.086	6791455.370	6791476.050	6791477.599
ISLAND_TURK	470182.299	470089.892	470093.855	470093.971
COAST_GREEK	2729884.068	2729383.322	2729378.051	2729370.655
CONNECTION_LINE	328529.493	328445.532	328449.064	328450.114
ISLAND_GREEK_MIX	948645.503	948457.287	948459.723	948461.388
AEGEAN BASIN	6335699.507	6334459.757	6334486.926	6334483.371

Table 6. The differences from the length of geodesic (m)

Layer	λ_o=21°	λ_o=25°	λ_o=27°
COAST_TURK	-466.827	-440.355	-439.242
ISLAND_GREEK	-1320.716	-1300.036	-1298.487
ISLAND_TURK	-92.407	-88.444	-88.328
COAST_GREEK	-500.746	-506.017	-513.413
CONNECTION_LINE	-83.961	-80.429	-79.379
ISLAND_GREEK_MIX	-188.216	-185.780	-184.115
AEGEAN BASIN	-1239.750	-1212.581	-1216.136

During juridical discussions on the water area liability between countries, the main problem is often the comparison of the areas of islands and their percentage to the total water area. Therefore the method which is used for the area calculations is very important and critical.

UTM system is based on the ellipsoidal transverse Mercator projection, which has a cylindrical and conformal feature. Conformal projections distort the areas, and are not suitable for area comparison. In order to analyse the distortions in the area values obtained from the UTM coordinates, it is decided to use an equal-area projection. The Lambert azimuthal equal-area projection is selected for this purpose. The plane coordinates are computed for this projection using ellipsoidal longitude and latitude values obtained from the inverse solution (Snyder 1982). The area values for the total Aegean basin are calculated using UTM coordinates with central meridians 21°, 25° and 27° respectively and using the Lambert equal-area projection coordinates. The results are presented in Table-7. The differences of the areas from the area obtained from the equal-area projection are shown in Table-8 (Goksel *et al.*, 2001).

Table 7. The Aegean water area (km^2)

Area computed from the Lambert equal-area projection coordinates	206964.50
Area computed from UTM coordinates (λ_o=21°)	207555.01
Area computed from UTM coordinates (λ_o=25°)	206964.84
Area computed from UTM coordinates (λ_o=27°)	206990.66

Table 8. The area comparison of the Aegean water area (km^2)

	(λ_o=21°)	(λ_o=25°)	(λ_o=27°)
Difference	-590.52	-0.34	-26.16

The centre point for the Aegean Sea is calculated as φ_o=38°17′27″ and λ_o=25°04′49″. The area reduction values are also computed using these coordinates according to the central meridians 21°, 25° and 27° respectively by using Gaussian radius of curvature as 6373.363km for the central latitude (Maling 1992). The differences from the true area are also compared with the area reduction values and the results are shown in Table-9 (Goksel *et al.*, 2001).

Table 9. Comparison of the differences with the area reductions (km^2)

	(λ_o=21°)	(λ_o=25°)	(λ_o=27°)
Area Reduction	-649.041	-0.251	-143.618
Difference	-590.516	-0.340	-26.160

5. CONCLUSION

The aim of this study was to determine the geometrically improved natural coastal line of Aegean Sea. For this purpose the Landsat MSS Satellite imagery was used. The accuracy of the results is limited to spatial resolution of this imagery. In the case of using of national topographic maps of Turkey and Greece, some important problems could occur as; un-homogeneous data, different projections, scale and cartographic generalisation level of national map sets, different production time of map sets, different data acquisition and evaluation methods and different data sources.

The benefits of the natural coastal line of this study are summarised as follows: up to date satellite imagery was used for research time; the satellite imagery is more reliable than existing maps; the coastal line was digitised according to objective criteria; the spatial accuracy is sufficient for global analysis of Aegean Territory.

On juridical discussions for determining the baseline between Turkey and Greece in the Aegean Sea it is suggested that it will be more reasonable to study with the UTM coordinates computed for a non-standard central meridian such as 25° which goes through the middle of the Aegean region. By calculating distances or the lengths of coastlines, the distance reductions bring sufficient results. It is also suggested that it is necessary to select an equal area projection for area calculations. If this is not possible, in that case it is highly recommended adding the area reduction values to the areas obtained from the UTM coordinates.

For future studies about same subject to reach excellent results, it is also suggested to use homogeneous distributed data collected from satellites of the Global Navigation Satellite System (GNSS) and remote sensing images which provide higher resolution than Landsat MSS. Golobal Digital Elevation Models such as SRTM DEM and ASTER GDEM can also provide reliable coast line information (NASA 2015, Japan Space Systems 2015).

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PHYSICAL OCEANOGRAPHY OF THE AEGEAN SEA: A REVIEW

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1. Introduction

As a connected to the Black Sea from north through Turkish Strait System and to the Levantine and the Ionian Sea from south, physical oceanographic characteristics of the Aegean Sea is defined by the water masses from these seas as well as local atmospheric forcing which leads to formation of new water masses and driving of circulation.

The studies towards the understanding hydrography and circulation of the Aegean Sea goes back to oceanographic studies carried out by Nielsen (1912) in the beginning of the 20th century. The review of these earlier studies can be found in Ünlüata, 1986. Following these earlier works, the limited studies on the physical oceanography of the Aegean Sea were carried out until 90s. Systematic observations after 90s both through national and international programmes have contributed substantially to our understanding of the physical oceanography of the Aegean. Results of these observations and modeling studies based on these observations are communicated through scientific publications. (e.g. Balopoulos and Collins, 1999 and papers published in this special issue, Georgopoulos *et al*., 2000; Theocharis *et al*., 1993; Roether *et al.*, 1996).

In the beginning of the 90s, synchronously with these systematic studies, the abrupt change in Aegean Sea physical oceanography, called Eastern Mediterranean Transient (EMT), occurred. During EMT, The Aegean Sea waters became densest in its known history and sunk to the bottom of the Eastern Mediterranean to form Eastern Mediterranean Deep Water (EMDW). Previously, it was known that only source for EMDWs is the Adriatic Sea and the Aegean Sea water can sink only to limited depths in Eastern Mediterranean. This sudden climatic change attracted many researchers to understand mechanism(s) triggered this event and its possible impact on the physical and biogeochemical dynamics of the Mediterranean at large. Hence, majority of the recent studies focused on understanding the EMT and its consequences. Because, it could be helpful to understand the how climate change will affect the ocean.

Institute of Marine Sciences and Technology of Dokuz Eylül University have been carried out oceanographic cruises in the Aegean Sea with R/V K. Piri Reis since

1991 to collect data for different projects. The data collected during these cruise were helpful first to understand the oceanography of the Aegean Sea, and secondly, it was corresponding to the period of EMT and post-EMT. In this paper we will review the physical oceanography of the Aegean Sea mostly based on the publications based on this data set supported by other studies. Hence, this review shows our contribution to Aegean Sea oceanography, not complete review of the studies as a whole. In the following sections, after reviewing basic geographical features of the Aegean Sea relevant to its physical oceanography, we will present the current knowledges on the atmospheric conditions, water masses structure, circulation and climatic changes occurred.

2. Geographic setting

The Aegean Sea has very irregular coastline with existence of small and large many bays and peninsulas. The existence of more than 3000 islands and islets together with this irregular coastline forms small basins and passages (Figure 1). This complex structure results in very complicated bathymetry. Aegean Sea connected to the Levantine and Ionian Seas from south through Cretan Straits. To the north, connected to the Sea of Marmara- Black Sea through Strait of Çanakkale. Although there are many small basins, five major basins are clearly identified. Cretan Sea is the largest and deepest basin located on the southernmost part of the Aegean Sea with maximum depth of 2500m. Between Cretan Sea and the mainland Greece Mirtoan Sea is located. In the central part of the Aegean, Chios and Skyros basins are situated. To the north, there exists the second largest basin of the Aegean named as North Aegean Through, which depth reach 1500m. As it will be presented below, these basins and connections to neighboring seas play crucial role in development of the circulation patterns and formation of the water masses in the Aegean Sea.

The wind climate of the Aegean is subject to winds associated with the cold outbreaks arriving from the north and cyclones arriving from the west as well as local and regional winds due to the influence of the orography. In the region, southeasterly and northwesterly winds dominate throughout the year with an average speed of 3.64 m/s except in the areas where canalizing effect of the valleys can determine the wind direction.

In order to display long term anomalies in the atmospheric conditions, we used the data from coastal meteorological stations from Turkish coast covering the basin from north to south. Monthly time series of wind stress anomalies for 1970-2007, depending on the availability of the data, were constructed from hourly wind measurements (Figure 2).

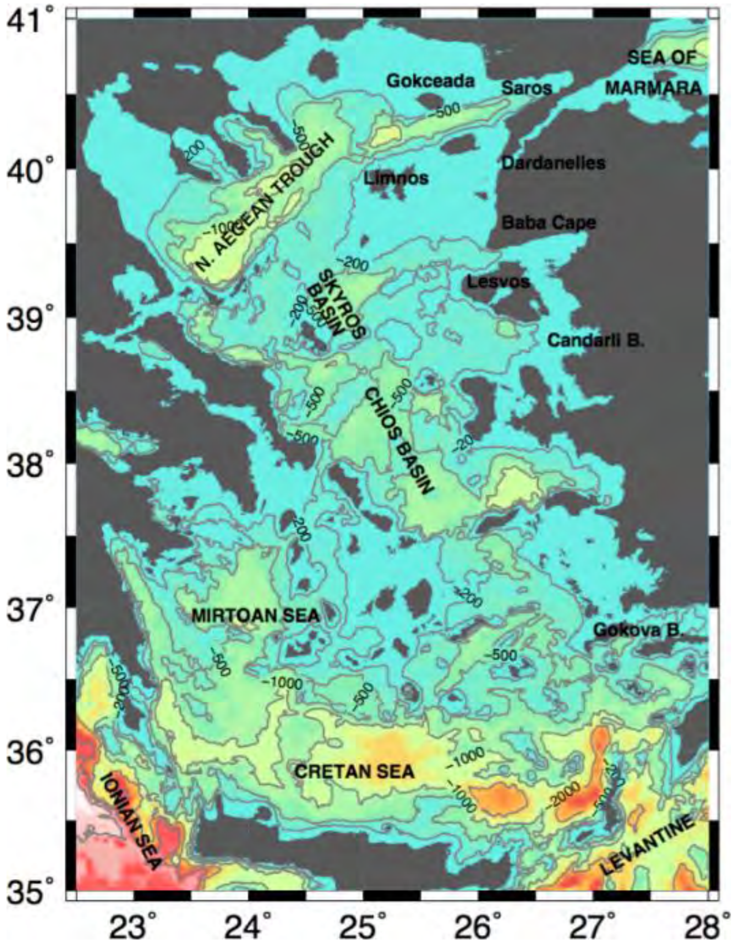

Figure 1. Aegean Sea and topography. Data is taken from the GEBCO_08 Grid, version 20090202 (http://www.gebco.net).

Based on the monthly wind stress anomalies, there are considerable geographical differences in magnitude and decadal variation. In the southern region (Kuşadası), wind stress anomalies display decreasing tendency over the past several decades. Northern region exhibits greatest scales of decadal variation in wind stress anomalies and does not any decreasing trend as observed in the south. The northernmost region is under the influence of the Saroz Bay and wind is strongest and mainly from NE along the axis of the bay. Although the wind stress anomalies in the southern region (Kuşadası) have become decreasing in long term, the decadal variation is also obvious.

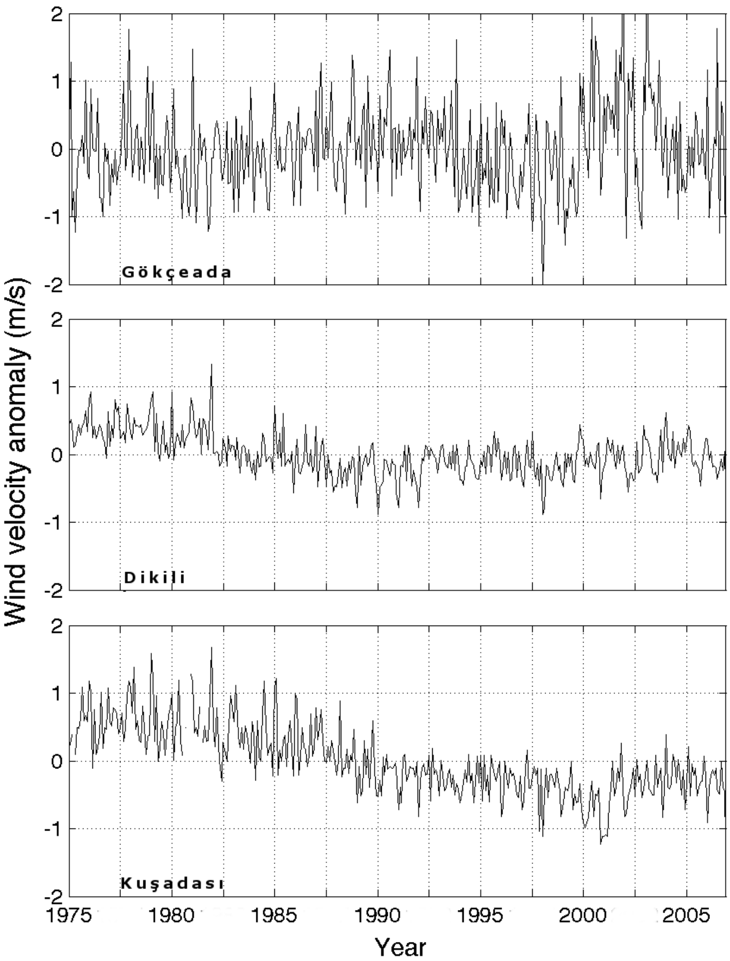

Figure 2. Anomalies of the wind measured at three meteorological stations along the Turkish coast from south to north; Dikili, Kuşadası and Gökçeada. Data is obtained from Turkish State Meteorological Service.

1. Water masses

Aegean Sea water masses are formed from combinations of Black Sea and Levantine Sea as well as locally formed water masses due to the atmospheric cooling-heating. Rivers input can also contribute to Aegean sea waters but is limited. Distribution of water masses and their volumes are presented in Figure 3 for winter 1988 (Gertman *et al*., 2006). Based on this study, six different water masses in the Aegean Sea are identified which exist throughout the year with different intensities and volume, namely; Black Sea Water (BSW), Levantine Intermediate Water (LIW), Aegean Intermediate Water (AgIW), Cretan Deep Water (CDW), North Aegean Deep

Water (NAgDW) and Central Aegean Deep Water (CAgDW). At the surface low salinity and colder BSW coming from the Çanakkale Strait and the high salinity and warmer LSW coming from the Levantine Sea through Cretan Arc Straits are found. Deep and bottom layers of the Aegean Sea is filled by the locally formed three different water masses; NAgDW, CAgDW and CDW from north to south and from denser and lighter. It is noted that densest deep waters are present in the northern part of the Aegean Sea indicating cooling at shallow regions of the north during winter. Between these surface and deep waters, AgIW are found. Among these water masses, while BSW volume is minimum, volume of the AgIW is maximum. According to their volumes water masses can be ordered from minimum to maximum as BSW, LSW, AgIW, CDW, NAgDW and CAgDW. Although the volumes of these water masses were changing inter-annually this order remains same. After EMT, all the waters of the Aegean Sea replaced with intrusion of extensive amount of water from Levantine Sea (Vervatis *et al*., 2011) and the above water masses are reformed. The transient Mediterranean water (TMW) with the salinity less than 39 is located underneath the AgIW (Balopoulos *et al*., 1999; Theocharis *et al*., 1999a). This water mass enters the south Aegean through the Cretan Arc Straits to balance the water left Aegean Sea during EM (Gertman *et al*., 2006).

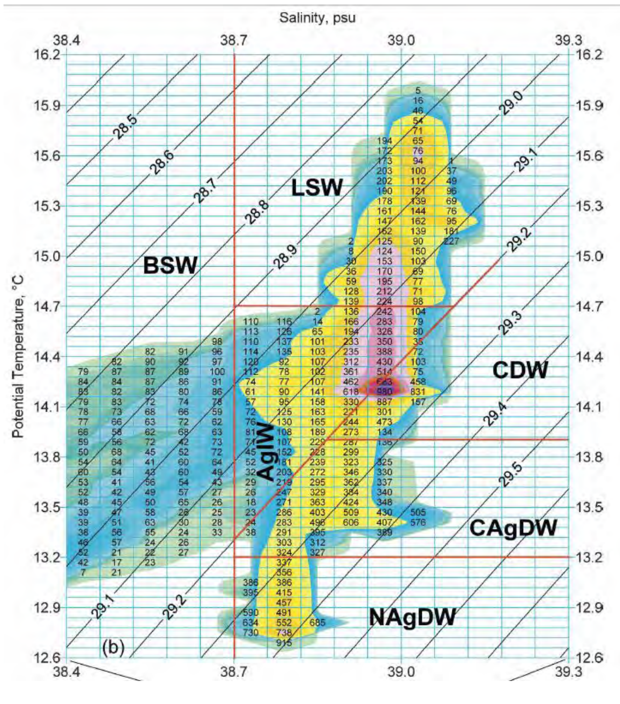

Figure 3. The θ–S diagrams and water mass distribution during winter 1988. Numbers within the cells are average depth of the water. Red lines areisosurfaces indicating the boundaries between water masses. (after Gertman *et al*., 2006)

2. Circulation

The basin scale circulation of the Aegean Sea is cyclonic and first presented by the Ovchinnikov (1966). The waters entering from the Levantine Sea moves towards north along the north compensated by the southern current along the coat of Greece. Existence of islands and complex topography and meteorological conditions create meso-scale cyclonic and anti-cyclonic eddies throughout the basin (Uçkaç, 2005). The schematics of the Aegean Sea circulation including all these eddies in different scales are presented in Figure 4 (Sayın *et al*., 2011). One cyclonic eddy, on the central part of the Aegean Sea forms and the another one occurs in the Chios Basin (Chios Eddy). These two eddies play a crucial role in the occurrence of the EMT as described above. Warm and saline Levantine waters penetrate into the Aegean through the eastern straits of the Cretan Arc. LSW starts to transform extensively in the Central Aegean Sea due to cooling on the way to the north and by mixing with the saline and cold upwelling water coming from north. Circulatory features of the Aegean Sea is also depicted from drifter measurements (Olson *et al*., 2007) in greater details.

Black Sea waters enter the Aegean Sea through the Strait of Çanakkale and circulates anticyclonically in the Northern Aegean. Pathway and seasonal variability of this flow can be seen more clearly from drifter measurements carried out during autumn and winter months (Figure 5). Cyclonic tendency of the basin scale flow is quite obvious from drifter measurements in both seasons.

During autumn, drifters released from mouth of the Dardanelles moves directly towards Greece and turns south along the Greek cost after. The cyclonic eddy at the central part of the Aegean Sea is obvious. Winter case is somehow different than this autumn case. Black Sea water upon exiting the Strait of Çanakkale turns north and forms anticyclonic circulation in the North Aegean. This shows effect of the southerly winds blowing dominantly during the winter in the Aegean. Although, number of drifters is limited during winter, the cyclonic tendency of the mean circulation can clearly be identified from one drifter escaped from anticyclonic eddy formed in the North Aegean.

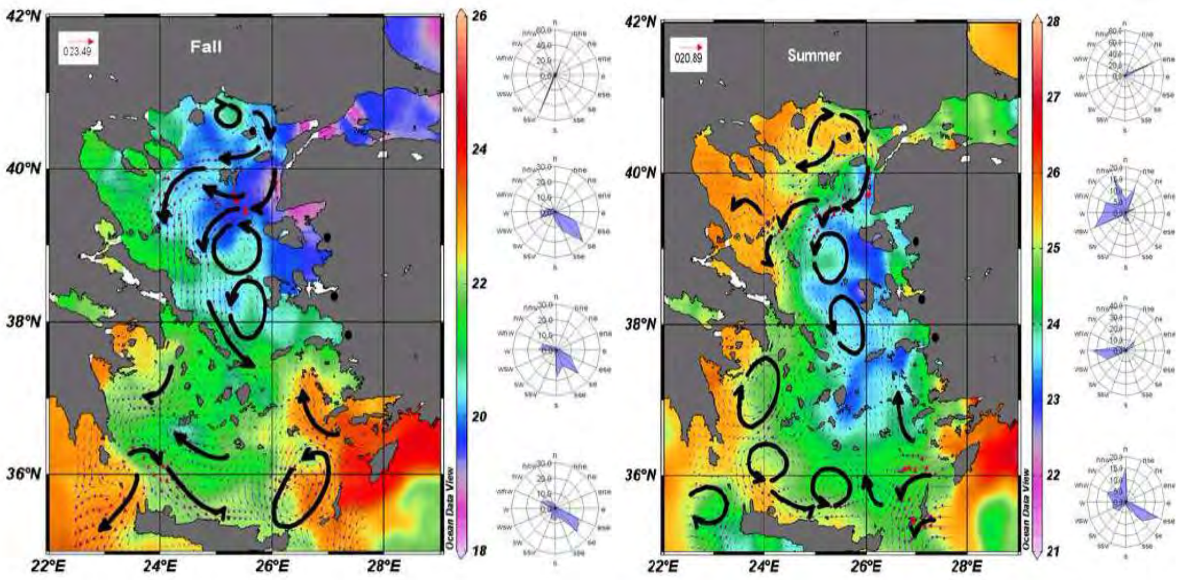

Figure 4. Schematic of the general circulation pattern of the Aegean Sea overlapped on the average SST values of 1991 of the corresponding season. The wind roses generated from the wind data obtained from the meteorological stations (black points) Gokceada, Dikili, Izmir and Kusadasi are shown at the right of each plot showing the dominant wind directions with their percentile occurrence. (after Sayın *et al*., 2011)

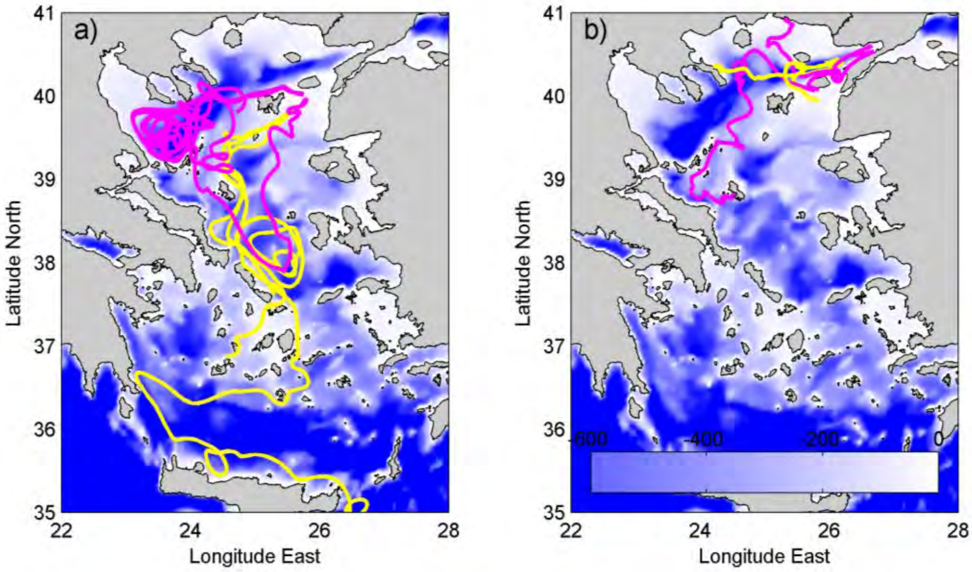

Figure 5. Drifter trajectories during the autumn 2008 (a) and winter 2009 (b) experiments. The drifter of the northern triplets are indicated in magenta colour, while the drifters of the southern triplets are depicted in yellow colour. The bathymetry is saturated at -600 m. (after Gerin *et al*., 2014).

3. Effect of climate changes

The Adriatic has been historically considered as the main contributor to the deep water of Levantine Basin (EMDW). However, the Aegean water began to flow to the deep of the eastern Mediterranean (Roether *et al*., 1996). The source of EMDW had shifted from the Adriatic to the Aegean Sea. It was a drastic change in the thermohaline circulation of the eastern Mediterranean with this new source water. This abrupt shift has been named as Eastern Mediterranean Transient (EMT).

EMT is and will be the big interested phenomena further to investigate. Because, it is a clear evidence of how local atmospheric conditions can cause big changes in the marine environment as well as indicating new site for the source of the EMDW. Starting from first observation of the phenomena (Roether *et al*., 1996). It was studied by a lot of authors (Klein *et al*., 1999; Lascaratos *et al*., 1999; Theocharis *et al*., 1999a). Malanotte-Rizzoli *et al*. (1999) have pointed out mainly that the EMT event clearly started before 1991. Some studies are asserted that EMT started in the years following 1987, earlier than 1990 (Schlitzer *et al*., 1991, Theocharis *et al*., 1999a). Gertman *et al*. (2006) has reported that CDW already began overflowing the sills of the Kassos and Antikithira Straits even during the winter of 1988.

The exact mechanism that forced the EMT is not completely known. But some how the increasing the densities in the Aegean Sea causes this big change. Deep waters in the Aegean Sea became first saltier between the years 1987 and 1991 according to the study of Lascaratos *et al*., (1999) and then saltier and cooler from 1991 to 1995 (Veloaras and Lascaratos, 2005). We can list the causes and studies concerning the increasing isopycnal levels in the Aegean Sea, such as: (i) redistribution of salt (Roether *et al*., 1996 and Klein *et al*. 1999). The entering high salinity Levantine waters into the Aegean because of the changing of wind stress in the early 1990s causing the modifications in the pathways of the intermediate waters (Samuel *et al*., 1999, Demirov and Pinardi 2002), (ii) Increasing winter convection, dense water formation due to cooling events in 1987 and 1993 (Theocharis *et al*., 1999b, Lascaratos *et al*., 1999, Eronat and Sayın, 2013) which was exlained as an increased latent and sensible heat loss fluxes during the winter in the Aegean which are related to the intense cold and dry northerlies (Vervatis *et al.*, 2013), (iii) low water outflow from the Black Sea enhancing air-sea interactions (Zervakis *et al*., 2000), iv) Forming of cyclonic circulation in the Central Aegean Sea bringing dense and cold intermediate water near surface. The surface water temperature is further decreasing due to open sea convection. In a modeling work by Nittis *et al*. (2003), Deep water is found to be formed mainly through open sea convection, where cyclonic circulation favors this mechanism in the Skyros and Chios basins. Open sea convection is very complimentary to winter mixing (Zervakis *et al*., 2004), v) Upwelling processes occurring in Saros and Baba Cape regions cause to forming dense coastal water. The forming dense coastal water is carried to the Central Aegean Sea by the strong northerly winds.

The EMT event can clearly be seen in the time series measurement carried out at the south of Limnos island (Figure 5). This area correspond the area where the cyclonic Central Aegean gyre exists. It is seen that the large amount of dense water formed during the winters of 1992 and 1993 in this area due to the extreme cooling and the increase of the salinities due to the increased evaporation. Due to the increasing inflow of the Levantine surface waters after this event during 1994 and 1995 [Kontoyiannis *et al*., 1999; Thecoharis *et al.*, 1999b] lighter waters filled the area due to the increased temperature. This phenomena is observed regularly and repeated itself in the witer of the 1996. However, it was not strong enough to repeat EMT again.

4. Conclusions

The general characteristics of the physical oceanography of the Aegean Sea are reviewed. Our knowledge on the physical oceanographic characterics of the Aegean Sea has been improved during last 2-3 decades considerably. Its circulation and water mass characteristics are identified and their time and space variabilities are well understood. However, internal dynamical process occuring in the Aegean Sea are still poorly known. In order to understand internal dynamical processes governing mesoscale dynamics and the rolo of the Black Sea waters on the dynamics of the Aegean Sea are not known clearly. Understanding of these processes are crucial and requires designing special process studies.

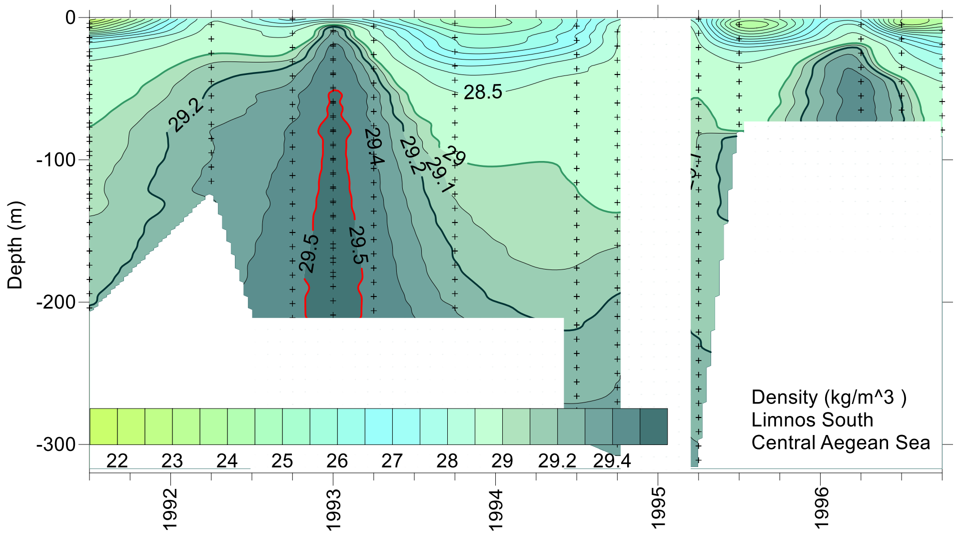

Figure 6. Temporal evaluation of density (sigma-theta) at the south of the Limnos Island starting from summer 1991 up to fall 1996. The areas in white represent where data absent (after Sayın and Beşiktepe, 2010).

Abrubt change in water mass characteristics and becoming a region for source of the deep waters of the Eastern Mediterranean made Aegean Sea very useful site for climate change research. Because, Change happened and can happen fast, on the time scale of a human lifetime. Thus, the Aegean Sea and the Mediterranean Sea provide a laboratory-type environment for documenting changes within it (and hence anticipating similar changes in the global ocean) and for understanding the role of key processes involved in climate change making inferences on processes occurring also at the global scale.

It is now evident that the 'conveyor belt' circulation in the entire Mediterranean is undergoing change, as evidenced by increases in deep water temperature and nutrient concentrations mostly as a result of changes in the Aegean Sea. On the other hand, abrupt changes in surface circulation and water mass have been recognized on decadal time scales, triggering series of modifications in the hydrology and dynamics of the entire Eastern Mediterranean.

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INTERACTION OF THE AEGEAN SEA WITH THE TURKISH STRAITS SYSTEM IN TERMS OF FLOW AND WATER MASS CHARACTERISTICS

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1. Introduction

The Turkish Straits System (TSS) is formed by the Sea of Marmara (70 x 250 km) with openings to the Aegean and Black Seas through the Strait of Istanbul (Bosphorus) (length 35 km, width >0.7 km) and the Strait of Çanakkale (Dardanelles) (length 75 km, width >1.3 km). The northern part of the Sea of Marmara comprises three elongated depressions (maximum depth ~1350 m) interconnected by sills (depth ~600 m) and flanked by a wider continental shelf on its southern side and a narrow (~10 km) shelf along the northern coast by steep topographic slopes. The sills located near the southern and northern exits of the Istanbul Strait and the constriction region 5 km north of the southern sill are the major morphological features controlling the two-layer exchange flow (Oguz *et al*., 1990). Similarly, the sharp bend of the strait geometry at the Nara Burnu Passage of the Çanakkale Strait exerts major modifications in the flow and stratification characteristics (Oguz and Sur, 1989). The Northern Aegean Sea (NAS) has a complex topography characterized by numerous islands, straits, peninsulas and a combination of shallow and deep basins. Two major shelf areas (< 200m) occupy the west-southwest of the Çanakkale Strait (Limni Plateau) and to the north-northwest and along the Thracian coast (Semadirek Plateau). They are separated by a zonally oriented narrow through zone deeper than 1000m (Limni basin). Main topographic features of the NAS are shown in Figure 1.

The Black Sea water rich in dissolved organic and inorganic carbon and nutrients plays a key role for sustaining high biological productivity and dense fish stocks in the North Aegean (Petiakis *et al*., 2014). The interannual-to-decadal changes in its water mass properties govern the deep water mass formation process and thus ultimately control the large scale thermohaline structure of the eastern Mediterranean (Velaoros and Lascaratos, 2010). In addition, the Black Sea outflow characteristics in the junction region and its subsequent buoyancy-driven transport pathways within the northern Aegean provide one of the best examples of the buoyant surface outflows.

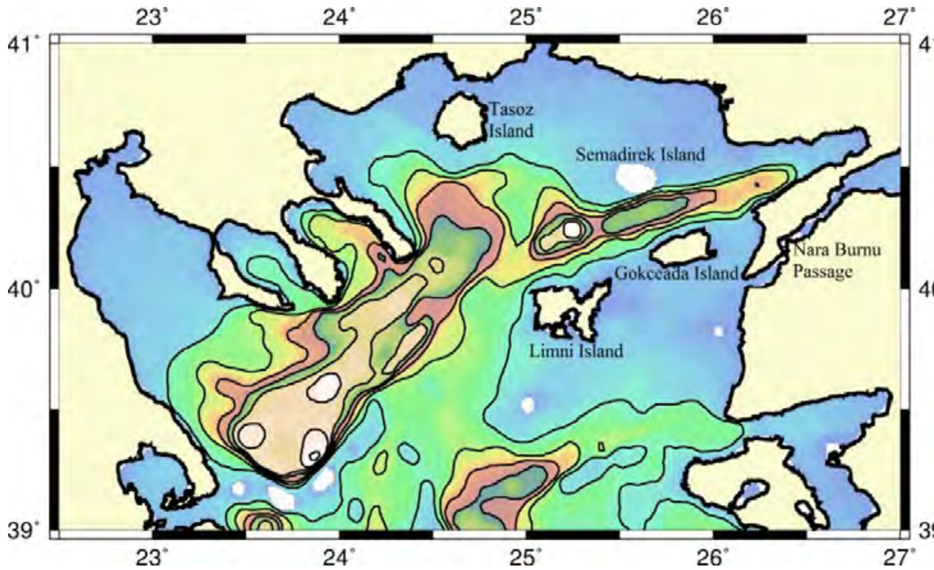

Figure 1. Bathymetry and main features of the North Aegean Sea.

Recent advances in both observations and modeling have allowed better understanding of the factors that influence the transport pathways of the Black Sea outflow and its impacts on the Aegean Sea physics and ecosystem over a wide range of spatial and temporal scales. This study elucidates our present understanding on the interaction of the Aegean Sea with the Turkish Straits System in terms of flow and water mass characteristics. The first part provides a brief review of the two-layer exchange flow characteristics along the Turkish Straits System with a particular emphasis given to its features at the Aegean exit of the Çanakkale Strait, based on the older studies documented by Unluata *et al*. (1990), Besiktepe *et al*. (1994), Eremeev *et al*. (1999), Tugrul *et al*. (2002), and more recent ones by Kanarska and Maderich (2008), Jarosz *et al*. (2012, 2013), Chiggiato *et al*. (2012), Gerin *et al*. (2013). The second part provides a synthesis on the outflow characteristics of the Black Sea water in the northern Aegean Sea based on the recent observational studies (Zervakis and Georgopoulos, 2002; Olson *et al*., 2007; Sylaios, 2011; Gerin, 2014) and the modeling studies (Tzali *et al*., 2010; Androulidakis and Kourafalou, 2011; Androulidakis *et al*., 2012).

2. Physical characteristics of the Turkish Straits System

The TSS possesses a two-layer system connecting highly stratified Black Sea and weakly stratified Aegean Sea. Its two-layer stratification is accompanied with the two-layer exchange flow system, which is driven by the density and sea level differences between the adjacent basins. The density difference drives the underflow from the denser Aegean Sea to the less dense Black Sea whereas the sea level difference drives the reverse upper layer flow towards the Aegean Sea. The location of pycnocline zone separating the upper and lower layer flows varies from 50 m below the sea surface near the Black Sea end of the Istanbul Strait to 20-25 m within the Marmara Sea and ~10 m near the Aegean exit of the Canakkale Strait. In the Marmara Sea, the upper 20 m layer is followed by sharp temperature and salinity variations immediately above the Mediterranean water mass (Figure 2). The interfacial density changes that are mainly controlled by the salinity differences are on the order of 7.0-13.0 kg m^{-3}. This difference is typically an order of magnitude greater than those observed in the Mediterranean Sea. The degree of stratification is subject to seasonal changes controlled by the local as well as remote hydro-meteorological conditions.

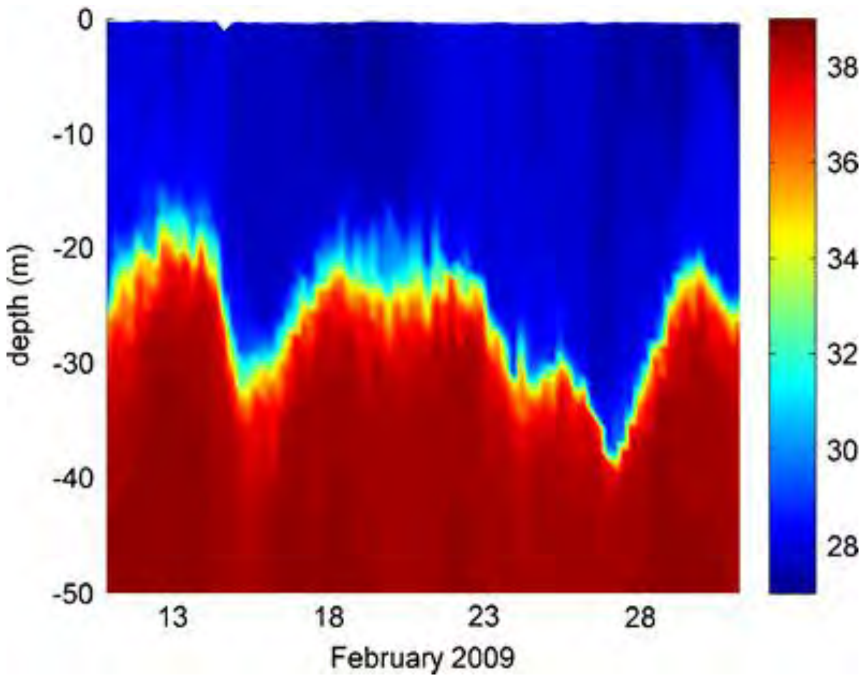

Figure 2. Vertical salinity structure measured by the bottom-mounted profiling instrument on the western side of the Marmara Island (Marmara Sea) during February. After Chiggiato *et al*. (2011).

The relatively dense Aegean Sea water mass enters the Canakkale Strait as an underflow below 10-15 m depths with salinity 39.1±0.1 psu and temperature 16±1 ºC (Jarosz *et al*., 2012). Their observed low frequency, subinertial variability in the ranges of 0.2 psu and 2ºC arises from the cooling/warming cycles and winter dense water mass formation. The underflow is subject to relatively minor changes along the Çanakkale Strait and its transition zone to the western Marmara basin except localized mixing at the Nara Burnu Passage. It then sinks into the deep basin as a dense plume with S~38.6-38.8 psu and T~15.0-16 ºC up to the density levels where they reside. The sinking may penetrate down to the bottom during winter owing to denser underflow due to lower temperature of the Mediterranean water mass whereas it is limited to the upper 100m layer below the interface in summer. The sinking plume takes part subsequently in the renewal of the sub-halocline waters of the Marmara Sea by spreading isopycnally in the form of intrusive layers. The underflow spends at most 6–7 years in the deeper layers of the Marmara basin (Besiktepe *et al*., 1994).

The lower layer water mass enters the Istanbul Strait through the submarine canyon with T~14.5-15.0 ºC and S~36-38 psu, and then interacts first with the southern sill and subsequently the constriction region its ~5 km downstream, and arrives at the northern exit with T~12.5 - 14.5 ºC and S~34-36 psu. There, its thickness of about 40 m at the Aegean end of the TSS reduces to 5-10 m at most. Downstream of the northern sill along the pre-Bosphorus channel and within the adjacent narrow shelf zone of the Bosphorus-Black Sea junction region, the underflow undergoes strong dilution due to its entrainment into the upper layer water mass. When it arrives at the southwestern Black Sea shelf break, it is identified as a thin plume with a thickness of less than 1 m and becomes almost indistinguishable from the ambient bottom waters of the region in terms of its temperature and salinity characteristics (Latif *et al*., 1991).

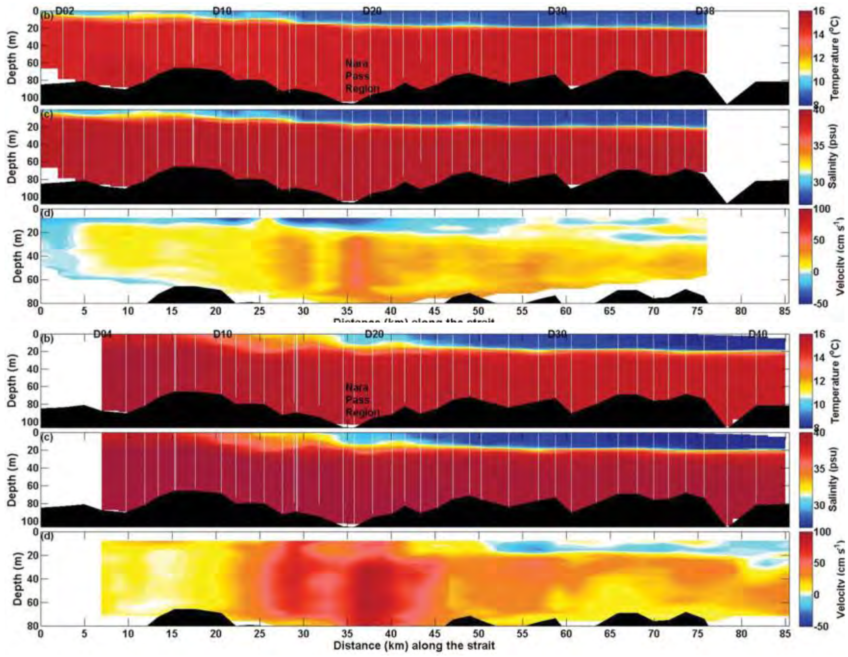

Figure 3. Along-strait variations of temperature (ºC), salinity (psu), and current speed (cm s^{-1}) (a) under weak-to-moderate northeasterly wind conditions during February 18, 2009 and (b) under strong southwesterly wind conditions during February 8, 2009. After Jarosz *et al*. (2013).

The upper layer water mass enters the Istanbul Strait from the Black Sea with salinity ~18.0-18.5 psu. It becomes subject to intense mixing at the constriction and southern sill regions and joins the Marmara Sea with S~20.0-21.0 psu. The upper layer water mass prevails relatively uniform conditions along the Sea of Marmara and upper half of the Çanakkale Strait up to the Nara Burnu Passage with S~21.0-23.0 psu during summer and S~24.0-27.0 psu in winter (Eremeev *et al*., 1999). The localized intense vertical mixing as it passes through the Nara Burnu Passage gives rise to further increase in its salinity to ~27.0-29.0 psu. Finally, the upper layer water mass joins the Aegean Sea as a thin layer (~10 m) with S~28.0-30.0 psu (Figure 3a). Based on the microstructure measurements (Jarosz *et al*., 2013) intense mixing at the Nara Passage was documented by almost two orders of magnitude increase in the depth averaged vertical eddy diffusivity and is related to the hydraulic adjustment of the two-layer exchange flow (Oguz and Sur, 1989; Stashchuk and Hutter, 2001; Kanarska and Maderich, 2008). The upper layer flow may also acquire supercritical conditions at the Aegean exit section occasionally (Oguz and Sur 1989; Jarosz *et al*., 2012). In winter, occasional southwesterly winds introduce strong mixing within the TSS in general and the Çanakkale Strait in particular. Under these conditions, the temperature and salinity of the upper layer water mass increases by about 2-3 ºC and 4-5 psu between the Aegean exit section and Nara Burnu Passage and the upper layer current speed reduces more than half (< 0.3 ms^{-1}), and may reverse temporally to flow in the direction of lower layer current. Under these conditions, the entire water column is characterized by the Mediterranean water mass properties up to the Nara Burnu Passage region (Figure 3b).

As suggested first by Besiktepe *et al*. (1994) and later by Gerin *et al.* (2013), the upper layer flow enters the Marmara Sea in the form of surface intensified buoyant jet in the south-southwest direction, curls anticyclonically north-northwest towards the northern coast afterwards, and proceeds along the topographic slope zone towards the Çanakkale Strait. A large anticyclone prevails in the northeastern or central area of the Marmara Sea under low wind conditions depending on the meandering path of the jet. This circulation pattern is often modified by several cyclonic and anticyclonic mesoscale eddies developed under strong wind episodes and flow instabilities as indicated by the drifter studies carried out during autumn (September 2008) and winter (February 2009) (Gerin *et al*., 2013). Eddies and associated flow patterns are modified under changing wind conditions between northeasterlies and southwesterlies (Chiggiato *et al.*, 2012).

Based on long-term salinity measurements and under the assumption of steady state conditions, the two-layer mass budget calculations (Unluata *et al*., 1990 and Tugrul *et al*., 2002) provided the mean annual upper layer transports as 27,500 (29,200) $m^3 s^{-1}$ and 40,000 (42,200) $m^3 s^{-1}$ at the Marmara and Aegean ends of the Çanakkale Strait, respectively. The slightly higher estimates given in parentheses are provided by Tugrul *et al*. (2002). In return, the lower layer water mass enters the strait at the rate

30,500 (32,000) $m^3 s^{-1}$ and leaves it with 18,000 (19,000) $m^3 s^{-1}$. The difference of 12,500 (13,000) $m^3 s^{-1}$ between the layer transports arises from the loss of approximately 40% of the lower layer water mass into the upper layer due to intense mixing at the Nara Burnu Passage. Their more recent estimates provided by the August 2008-October 2009 acoustic Doppler current time series measurements (Jaroz *et al.*, 2013) estimated the corresponding upper layer transports as 25,700 and 37,700 $m^3 s^{-1}$ and the lower layer transports as 31,700 and 14,000 $m^3 s^{-1}$. Thus, as far as the transports at the Aegean exit of the Çanakkale Strait are concerned, different estimates yield comparable annual mean values around 40,000 $m^3 s^{-1}$ and 32,000 $m^3 s^{-1}$ for the upper and lower layers, respectively. They are also consistent with those of 38,800 and 30,000 $m^3 s^{-1}$ provided by the modeling study of Kanarska and Maderich (2008).

The monthly mean transport estimates derived from the time series measurements at the Aegean exit section imply relatively low upper layer transport in fall 2008 (~33,000 $m^3 s^{-1}$) and high in winter-spring 2009 (~42,000 $m^3 s^{-1}$) suggesting nearly 4,000-5000 $m^3 s^{-1}$ changes with respect to the annual mean value. On the contrary, opposite conditions hold for the lower-layer flux (~25,000 $m^3 s^{-1}$ in spring and 37,000 $m^3 s^{-1}$ in fall with respect to the annual mean estimate (31,700 $m^3 s^{-1}$). The net transport therefore acquires its maximum (~17,000 $m^3 s^{-1}$) in winter-spring and declines to almost zero in fall.

The time series measurements also display two-to-three fold changes in the layer transports on synoptic (2-10 days) time scales with respect to their annual mean estimates (Figure 4). The ranges of fluctuations at the Aegean exit section corresponded to 47,000 - 82,000 $m^3 s^{-1}$ for the upper layer (Figure 4a) and 13,700 - 107,000 $m^3 s^{-1}$ for the lower layer (Figure 4b). The changes in local atmospheric forcing and the bottom-pressure anomaly gradients account for major part of the synoptic flux variability. Dynamical processes inside the strait and/or in the adjacent seas also contributed partially to the synoptic scale variability.

Near the Aegean exit of the Çanakkale Strait, the along-strait surface currents often exceed 90 cm s^{-1} and may be as high as 130 cm s^{-1}. They decrease linearly towards zero at depths around 15m, and the currents in the lower-layer with an average speed of 30 cm s^{-1} and occasional peaks up to 75 cm s^{-1} are observed at depth around 25-30m and declines gradually to low values towards deeper levels (Figure 5). The current structure in both layers also possesses both horizontal and vertical shears indicating non-zero relative vorticity of the upper layer flow as it enters the Aegean Sea (Jarosz *et al.*, 2012). This vorticity may likely play a role on the outflow characteristics of the Black Sea jet. An interesting feature of the current profiles shown in Figure 5 is occasional development of westward current towards the Aegean Sea near the bottom, thus giving rise to three layer current structure. This feature, however, is not persistent and the vertical current structure switch temporally between its two and three layer modes.

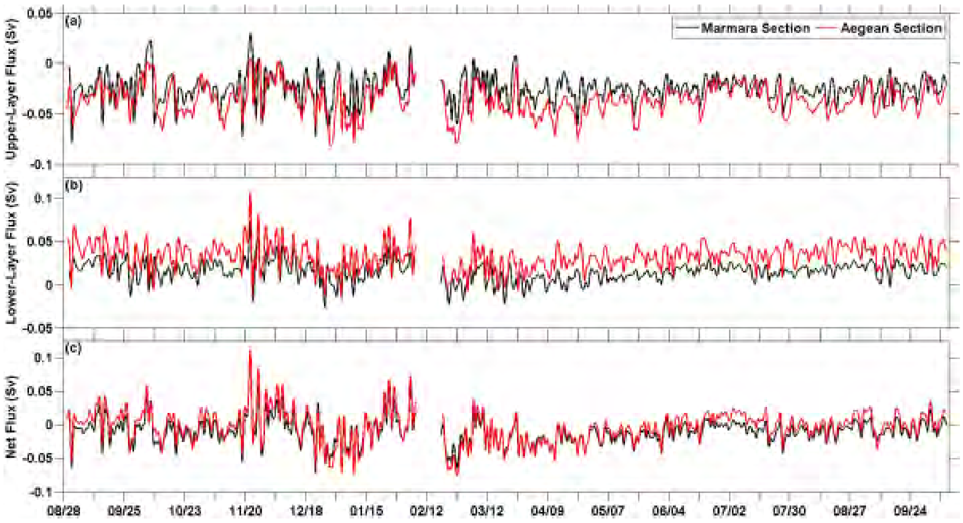

Figure 4. Times series of (a) upper-layer, (b) lower-layer, and (c) net volume fluxes (in Sv = 10^6 m^3s^{-1}) at the northern (black lines) and southern (red lines) end of Canakkale Strait (positive values—flux toward the Sea of Marmara; negative values—flux toward the Aegean Sea). After Jarosz *et al*. (2013).

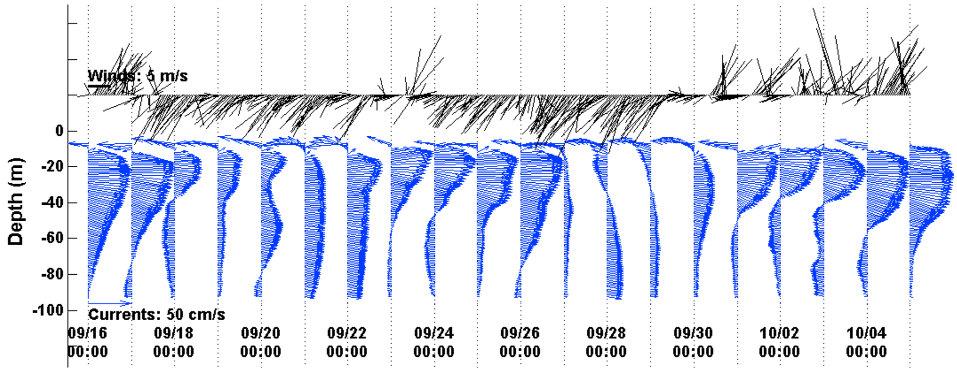

Figure 5. Current profiles (blue arrows; cm/s) measured at the Aegean exit section of Canakkale Strait, and winds (black sticks; m/s) measured at Çanakkale meteorological station during September-October 2008. After Jarosz *et al*. (2012).

3. Outflow characteristics of the Black Sea water in the Aegean Sea

The physical characteristics of NAS water masses are affected by the local meteorological conditions (in terms of prevailing winds, dense water formation, lateral transports, mesoscale variability, upwelling/downwelling vertical motions) and the supply of buoyant waters of the Black Sea origin (hereafter BSW) issuing from the Strait of Çanakkale. The region consists of mainly three distinct water masses. The uppermost ~20 m thick surface layer is occupied by the BSW. The BSW signal may cover the entire north Aegean and may even extend occasionally to the central basin (Olson *et al*., 2007). The Northern Aegean basin forms a large reservoir of relatively fresh water mass accumulation in addition to the dense water mass formation. It overlies the relatively warm and highly saline water entering from the South Aegean down to 350-400 m depth. The deep-basins below 400 m are filled by the locally formed dense water mass as the region constitutes one of the main dense water formation sites of the Mediterranean Sea. The general circulation comprises a series of permanent, semi-permanent and transient mesoscale features that are further modulated by the morphological features such as islands, complex coastline structures, and irregular bottom topography, as well as the regional atmospheric conditions.

The Black Sea water mass entering the Aegean Sea is traced by its cooler and fresher characteristics. It is separated from the warmer, more saline Aegean Sea surface waters by small scale temperature and salinity fronts around the exit section, Limni and Gökçeada Islands (Zodiatis, 1994), and on the larger sub-basin scale by a well-defined offshore salinity front. According to the available observations, this large scale frontal structure is located in the northeastern sector during winter-spring months when the Black Sea water mass signature weakens under intense vertical mixing and dense water mass formation (Figure 6a,b). In the absence of intense mixing during summer-autumn, the BSW however can spread over the entire north Aegean Sea and the front lies zonally along ~ 39.5^{o}N latitude (Figure 6c, d). These features appear to be robust as also inferred by the climatological data (see Figure 6 in Tzali *et al*., 2010).

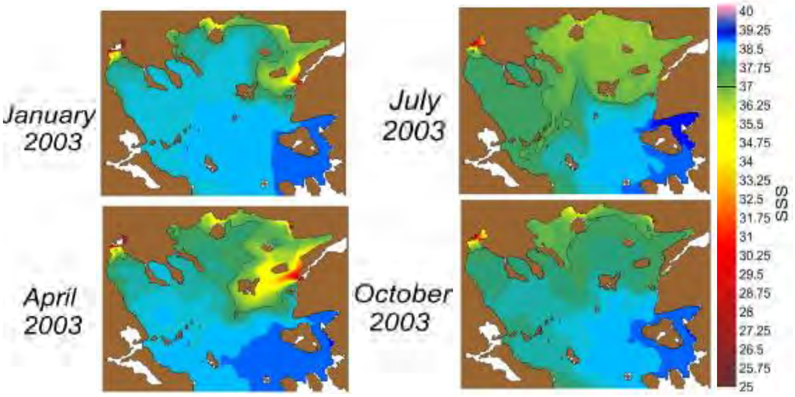

Figure 6. Mean monthly surface salinity distributions for winter(January), spring (April), summer (July) and autumn (October) during 2003.The black line indicates the 37 psu isohaline contour. After Androulidakis *et al*. (2012).

The outflow characteristics of the Black Sea surface water mass do not differ from the general features of the buoyant outflows observed elsewhere, such as the Atlantic jet exiting from the Gibraltar Strait into the Alboran Sea (Oguz *et al*., 2014) and the Bosphorus jet outflow into the Marmara Sea (Besiktepe *et al*., 1994). The BSW enters the Aegean - Çanakkale Strait junction region within the west-southwest sector, crosses the channel between the Limni and Gökçeada Islands, and then deflects anticyclonically towards north-northeast and then proceeds westward in the form of coastal current system along the Thracian shelf in the direction of Kelvin wave propagation. A fraction of the BSW may deflect northward immediately after exiting from the strait and flows as a coastally-attached current along the coast. Its northward deflection is accompanied with an anticyclonic eddy (the so-called Semadirek anticyclone) to the north of the exit section. This general outflow pattern is however subject to some temporal variations, and the surface jet may acquire alternative routes to spread. One of the preferred routes is to shoot southwestward along the axis of the Çanakkale Strait followed by its northward turning along the southwestern side of the Limni Island to support the Semadirek anticyclone (Androulidakis and Kourafalou, 2011). In some cases, the BSW does not turn northward but follows the westward or southwestward route after passing through either north or south of the Limni Island.

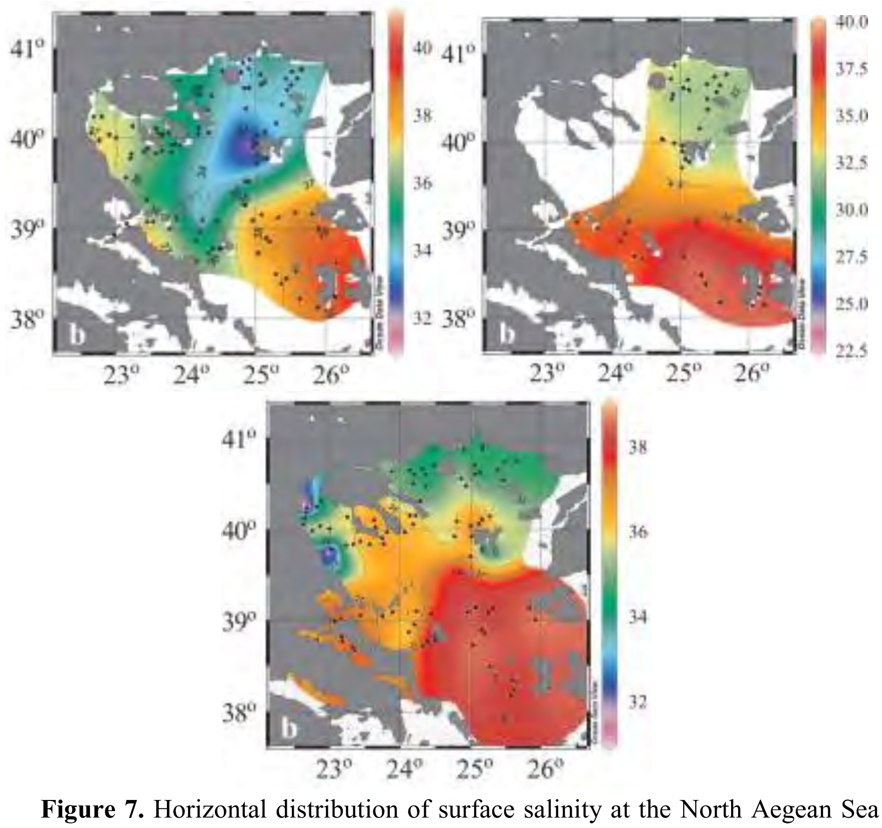

Figure 7. Horizontal distribution of surface salinity at the North Aegean Sea in (a) June 2000, (b) June 1999, (c) June 2001. After Sylaios (2011).

These alternative flow patterns may be inferred in Figure 7a-c. In the first case (indicating a strong outflow condition), the entire eastern half of the north Aegean Sea is occupied by the low salinity (< 34 psu) surface waters of the Black Sea origin (Figure 7a). This water mass is separated from the ambient Aegean Sea waters by a strong and laterally broad salinity front of 35-36 psu. Apparently the BSW exited from the Çanakkale Strait in the southwest direction and then deflected northward within the central basin of the NAS. In the second case (moderate outflow conditions), the salinity front extend diagonally in the NW-SE direction crossing the region between the Limni and Gökçeada Islands and separates the low salinity surface waters (< 33 psu) of the northeastern sector from more saline ambient waters elsewhere (Figure 7b). In the third case, the Black Sea outflow is confined more closely towards the Turkish coast with the front extending on the northern side of the Gökçeada Island with salinity (~ 35 psu). This case likely indicates a relatively low outflow condition (Figure 7c).

Another observational support for the first and second preferred routes of the BSW is provided by the May 1997 and September 1998 hydrographic measurements (Figure 8a,b). In May 1997, main path of the jet is oriented towards north after crossing the Limni-Gökçeada channel. A minor part circles around the Limni Island and joins the northward stream (Figure 8a). In September 1998, main path of the jet is southwest towards the central Agean Sea from the southern side of the Limni Island. A weaker component of the jet, however, acrosses the Limni-Gökçeada channel and supports the Semadirek anticyclone on the northeastern side of the basin (Figure 8b).

The additional observational support for these alternative patterns is given by the drifters that were released in the junction region of the Aegean Sea-Çanakkale Strait during September 2008 and February 2009 and followed during their lifetime on the order of one-to-four months (Gerin *et al*., 2014). Some of the drifters indicated westward movement of the BSW between the Limni and Gökçeada Islands and formation of a large cyclonic loop covering the entire northern basin and also a part of the central basin, and others involved the northward deflection and cyclonic circulation within the Gulf of Saroz and then proceeding either westward between the Gökçeada and Semadirek Islands or towards the northern coast.

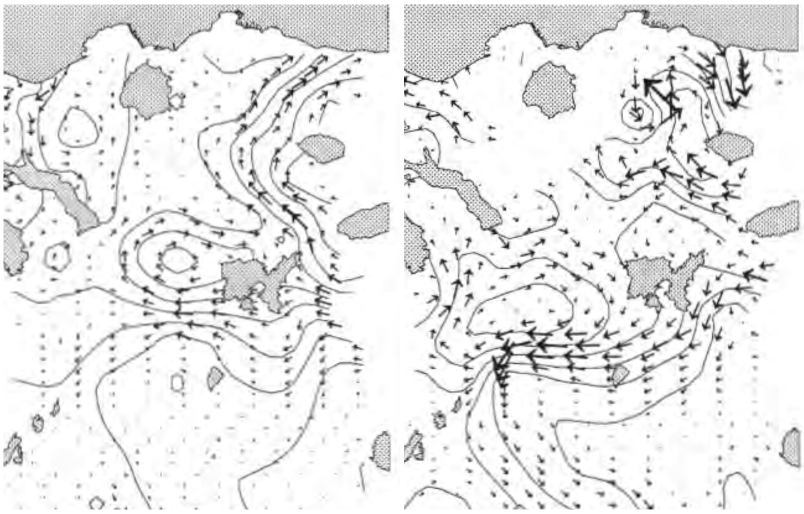

Figure 8. Distribution of the geostrophic currents at 5 dbar relative to 50 dbar in (a) May 1997 and (b) September 1998. After Zervakis and Georgopoulos (2002).

The process-oriented modeling studies (Androulidakis and Kourafalou, 2011) link these three likely routes of the jet to the outflow rates. In the case of low outflow rates (0.1Q = 1,000 m^3 s^{-1}), the jet is weak and flows northward as a coastally-attached current without any anticyclonic gyre formation (Figure 9a). The standard transport case (Q = 10,000 m^3 s^{-1}) provides a well-defined jet that passes through the Limni-Gökçeada passage and flows northward and then meanders westward along the Thracian coast (Figure 9b). In the case of stronger transport (10Q = 100,000 m^3 s^{-1}), the jet is directed towards southwest along the southern side of the Limni Island and meanders in the form of a westward jet as a miniature form of the open ocean frontal jets (Figure 9c). An alternative form of the westward jet takes place along the northern side of Limni Island and accompanies with eddies, meanders and filaments as shown in Figure 10. We note that these features shown by Figure 9a-c for low, intermediate and high outflow rates are very similar to the structure of the Atlantic jet issuing from the Gibraltar Strait (Vargas-Yanez *et al*., 2002).

Following the modeling studies by Androulidakis and Kourafalou (2011) and Androulidakis *et al*. (2012), when the wind forcing is weak the buoyancy-driven current system dominates the overall flow structure and the wind contribution plays a secondary role. Strong northeasterly Etesians (also called Meltem) winds that prevail most of the year limit the northward expansion of the outflow and force it to spread to the south of the Limni Island. The Semadirek anticyclone weakens or disappears temporally. This case resembles spreading of the strong buoyant outflow case in the absence (or weak) wind conditions. But it develops with weaker outflow characteristics and stronger northerly winds. Strong southwesterly winds that affect the region during November-March in response to the winter extratropical cyclones restrain the bulge formation around Gökçeada Island, push the surface waters towards the Turkish coast and the Soroz Gulf, strengthen the northward (downstream) buoyancy-driven current but weaken its westward turn upon arrival at the north coast.

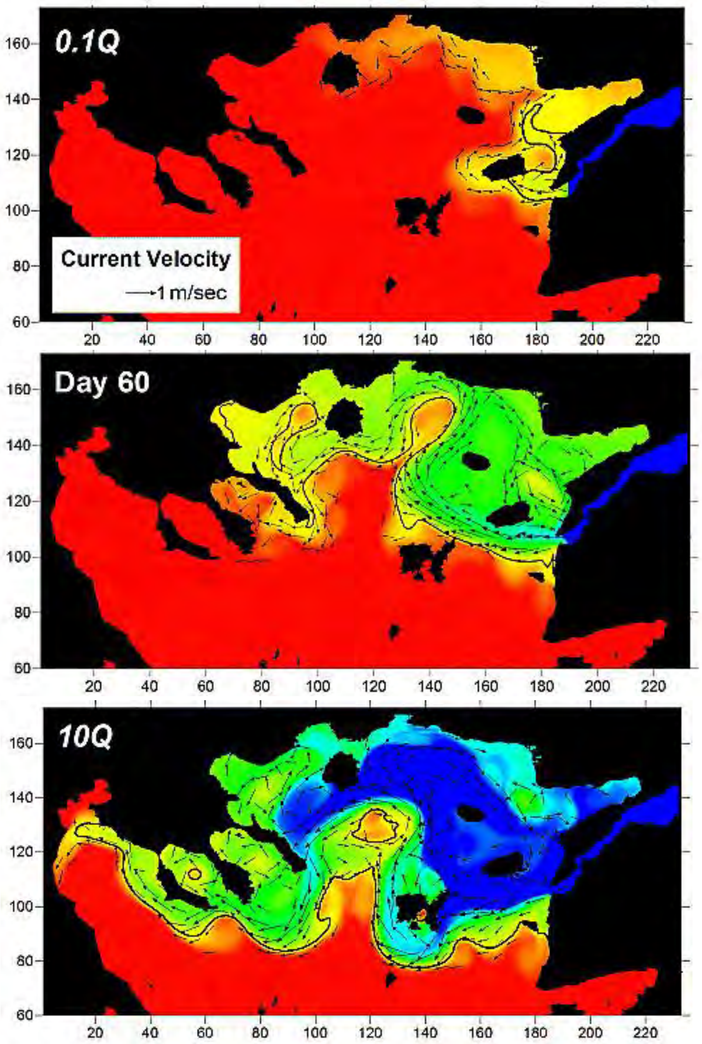

Figure 9. Sea surface salinity distribution and surface velocity vectors (m s-1) for the (a) low outflow (0.1Q), (b) moderate outflow (1Q), (c) strong outflow (10Q) conditions simulated by the model at day 60. The black line indicates the 33 psu isoline. After Androulidakis and Kourafalou, (2011).

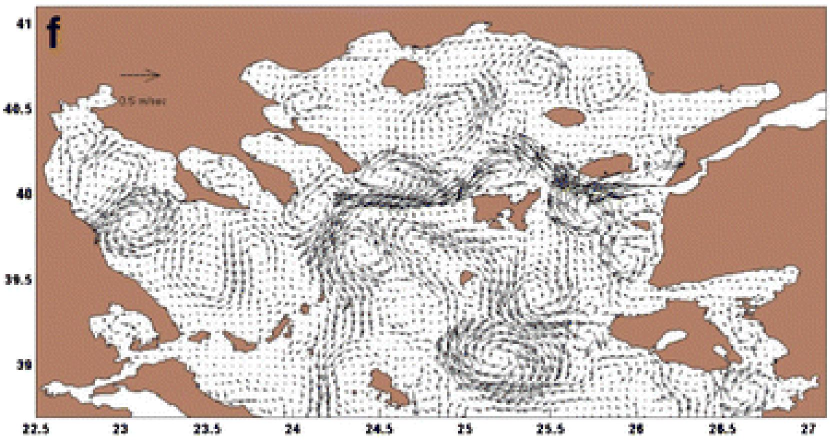

Figure 10. February and August mean surface circulation patterns driven by the climatological wind and thermohaline forcing and idealized sinusoidal type yearly Black Sea upper layer outflow. After Tzali *et al*. (2010).

4. Conclusions

The recent continuous time series measurements indicate a wide range of variability of the Black Sea outflow at the Canakkale Strait exit section (47,000 to 82,000 m^3 s^{-1}) on the synoptic scale (< 10 days). This variability is expected to introduce considerable high frequency variability on the NAS upper layer circulation that however has not been documented yet by the modeling studies. Issuing from the Canakkale Strait as a surface-intensified buoyant jet, the Black Sea outflow follows different paths depending on the outflow rate and prevailing wind conditions. In the case of low-to-moderate outflow rates, the jet preferentially follows an anticyclonic path towards north and then west along the Thracian shelf with its partial support to the Semadirek anticyclone. In the case of moderate-to-strong outflow rates, the jet is oriented towards west either from the northern and southern side of the Limni Island in the form of a meandering unstable jet as in the case of open ocean frontal jets. A part of the westward jet may bifurcate to proceed northward. In the latter case, the Black Sea outflow provides a more limited replenishment of the north-northeastern Aegean shelf with respect to the former case. Relatively strong northerly winds may shift the jet trajectory to the south of Limni Island whereas strong southerly winds reinforce its coastal attachment to the north of the exit section with limited offshore spreading. Winter mixing also restricts its basin-wide spreading and traps it mainly into the northeastern part, whereas its summer signal may cover the entire northern Aegean basin. It is, however, presently unclear how the mesoscale and submesoscale features associated with the quasigeostrophic (low Rossby number; Ro < 0.5) and ageostrophic (high Rossby number; Ro ~ 1.0) dynamics control the surface circulation patterns. In the case of westward meandering unstable jet mode, ageostrophic dynamics may promote high vertical velocities (10-100 m d^{-1}) and support enhanced biological production of the region.

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MARINE GEOLOGY OF THE AEGEAN SEA

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1. Introduction

Aegean Sea is a shallow, elongate embayment situated between Turkey and Greece (Figure 1). In the northeast, it is connected to the Black Sea through the Straits of Bosphorus (32-110 m deep) and Dardanelles (50-105 m deep). In the southwest and southeast several larger and deeper straits provide the communication between Aegean Sea and the eastern Mediterranean Sea (Hopkins, 1978): the Cervi (180 m), Kithira (160 m), Andikithira (700 m), Kasos (350 m), Karpathos (550 m), and Rhodes (350 m). The Aegean Sea has a surface area of ~2x10^5 km^2, corresponding to ~10% of the Mediterranean Sea with a total volume of ~74104 km^3 (Bruce and Charnock, 1965; Hopkins, 1978). Approximately 33.6% of the Aegean Sea is shallower than 200 m, and the mean water depth is ~362 m (Goncharov *et al.,* 1965).

Two primary north-facing, concave island arc systems characterize the morphology of the southern Aegean Sea. The Hellenic Arc extends from southern Peloponnesus towards the islands of Kithira, Crete, Kasos, Karpathos and Rhodes, thereafter passes into southwestern Turkey. Aegean Volcanic Arc is situated north of the Hellenic Arc, and extends southeast from mainland Greece towards the broadly arcuate Cyclades islands and thereafter swinging northeast toward mainland Turkey. Cretan Trough is an elongate depression, composed of a series of smaller sub-basins, situated between the Hellenic Arc and the Aegean Volcanic Arc. Water depth in the trough generally exceeds 1000 m, and sub-basins become successively deeper towards the east, with maximum depth exceeding 2591 m.

In the northern Aegean Sea, north of the Aegean Volcanic Arc, basin evolution is controlled by several east-west trending graben systems that are bounded by active normal faults; Galanapoulos and Delibasis, 1971; Arpat and Şaroğlu, 1975; Angelier *et al.,* 1981). The North Aegean Trough is a northeast-southwest trending depression bounded by the spays of the dextral North Anatolian Transform Fault system, with water depths generally exceeding 1000 m. North and South Skiros Basins are fault-bounded small depressions, 500-1000 m deep, situated south of the North Aegean Trough. North and South Ikaria Basins are also small fault-bounded depressions, 650-1000 m deep, situated north and south the Island of Ikaria, respectively.

There are two distinct types of continental shelves surrounding the Aegean Sea: (i) narrow (1-10 km) and (ii) broad (25-95 km) shelves. Narrow shelves dominate the western margin of the Aegean Sea and the fringes of more than 200 islands. The shelf-break in narrow shelves is primarily controlled by major bounding faults and generally occurs between 130 and 150 m with very steep slopes (up to 1:20) leading into deep basins. In most regions between the islands there is no clear shelf-break and the morphology of the sea-floor exhibits linear shore-parallel troughs. The broad shelves occur predominantly along the eastern and northern Aegean Sea. Except for the outlet of the Dardanelles, all are found seaward of major present-day deltas. The shelf-break in broad shelves occurs between 95 and 120 m water depth and denotes the topset to foreset transitions of deltas prograded during the end of last glacial period, immediately prior to Holocene transgression (Aksu *et al.,* 1987 a,b).

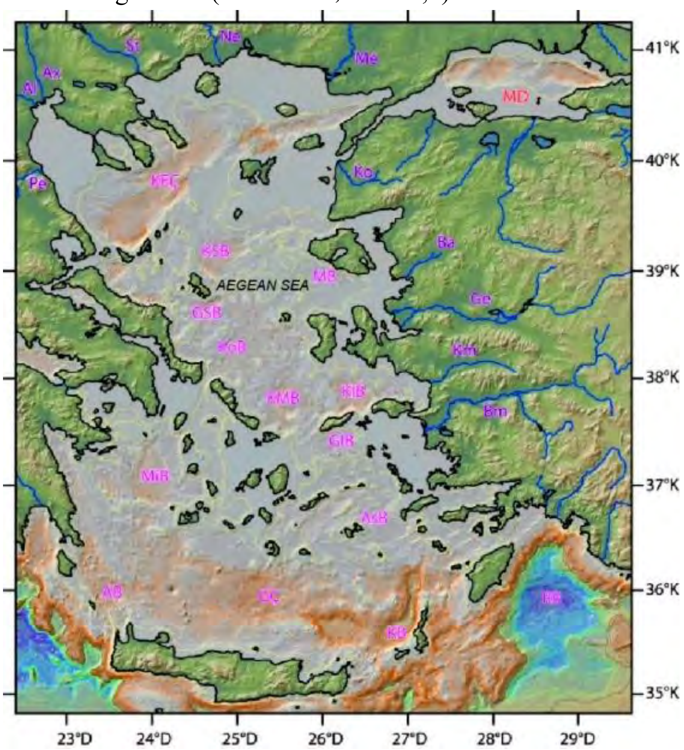

Figure 1. The Morphology of the Aegean Sea. AB= Argolikos Basin, Al= Aliakmon River, AsB= Astipalea Basin, Ax= Axios River, Ba= Bakırçay River, Bm= Büyük Menderes River, GÇ= Girit Basin, Ge= Gediz River, GIB= South İkaia Basin, GSB= South Skiros Basin, KB= Karpatos Basin, KEÇ= North Aegean Basin, KIB= North Ikaia Basin, Km= Küçük Menderes River, KMB= North Mikonos Basin, KoB= Koloyeri Basin, MB= Midilli Basin, MiB= Mirtu Basin, Ne= Nestos River, Pe= Peneios River, RB= Rodos Basin, St= Strimon River.

2. River Discharge into the Aegean Sea

Several major rivers discharge into the Aegean Sea, such as Meriç, Nestos, Strimon, Axios and Pinios discharge in the north and Bakırçay, Gediz and Büyük and Küçük Menderes in the east. The drainage area and monthly discharge rates of major rivers draining into the Aegean Sea discharge rates are given in Table 1 (data from: Therianos, 1974 and EIE, 1984).

Table 1. The drainage area and monthly discharge rates of rivers draining into the Aegean Sea.

Rivers	Draining area (km^2)	Average discharge ($m^3\ s^{-1}$)
Aliakmon	6075	72.8
Axios	22450	157.5
Bakırçay	2888	19.8
B. Menderes	23889	154.5
Gediz	15616	85.1
K. Menderes	3255	25.8
Meriç	45374	298.8
Nestos	4874	57.9
Pinios	7081	80.9
Strimon	10937	109.9

These rivers drain southeastern Europe and western Turkey with a combined annual water discharge ranging between 400 and 2400 $m^3\ s^{-1}$, and an annual average of 1063 $m^3\ s^{-1}$, or ~33 $km^3\ yr^{-1}$. This suggests an average annual sediment yield of approximately 229.1 million tonnes (EIE (1982). Aegean Sea also receives large quantities of Black Sea surface water at an average rate of ~1257 $km^3\ yr^{-1}$ through the Dardanelles (Oğuz *et al.,* 1991). Most of this outflow occurs during the summer (peak in August; Yüce, 1991), closely correlating with the maximum discharge of large rivers draining into the Black Sea, such as Dnieper, Dniester, Don, Danube and Bug.

3. Palaeoceanography of the Aegean Sea

Four hemipelagic lithofacies are identified in the late glacial to Holocene sediments in the Aegean Sea (Yaşar, 1994). These lithofacies are silty-clay and clay in texture and include an admixture of (i) loose terrigenous sediments directly supplied from the adjacent landmass, (ii) gravel- to sand-sized cemented carbonate clasts and nodules, (iii) sand- to silt-sized air-born volcanic debris and (iv) various biogenic remains. Sediment dispersal is mainly controlled by the fluvial discharge rates, the sea-level variations during the last ca 15,000 years, which determined the proximity of the Aegean basins to river mouths and the prevailing oceanographic conditions in the Aegean Sea. Cemented carbonate clasts and nodules occur throughout the cores except within the sapropel layer S1. They are well- to friably-cemented, mottled to peloidal micrite or microcrystalline inter-granular cement between terrigenous and bioclastic debris, and are composed of carbonate, in the form of 10 to 11 mole % magnesium calcite. Aragonite, in the form of pteropods and microcrystalline aragonite is present throughout the cores, and together with the cemented carbonate clasts and nodules, both in surface and subsurface sediments, indicate that shallow pore waters in the Aegean Sea are now and have been for at last 15,000 years, saturated to supersaturated with respect to both aragonite and magnesium calcite. XRD results show that Facies C (sapropel S1) is characterized by lower smectite, higher illite abundances, with notable increases in chlorite and a reciprocal decrease in kaolinite abundances. Lower smectite/illite and kaolinite/chlorite ratios are a function of increased supply of illite and chlorite and decreased supply of smectite and kaolinite during the deposition of this facies (Yaşar, 1994).

Late glacial to Holocene paleoclimatic and paleoceanographic changes are examined using records of calcareous and organic-walled marine microfossils, pollen and terrestrial spores and oxygen isotope data in cores from the Aegean Sea basins. Planktonic foraminiferal, coccolith and dinoflagellate data show that the last glacial - Holocene transition in the region was associated with a considerable warming in surface water temperatures. Paleotransfer function applied to planktonic foraminiferal assemblages show 5-10 ^{0}C increase in surface water temperature from ~14,000 to ~9,600 yrBP. Estimates of surface water oxygen isotopic composition ($\delta^{18}O_w$) derived from planktonic foraminiferal oxygen isotopic and transfer function data indicate that this warming was associated with a 2.0 to 2.5 $^{0}/_{00}$ reduction in $\delta^{18}O_w$. Mediterranean-based transfer function results indicate corresponding 1.0 to 1.5 $^{0}/_{00}$ salinity reductions between ~9,600 and 6,400 yrBP throughout the Aegean Sea. The early Holocene excess fresh water originated from rapid melting of the northern European and Siberian ice sheets, supplied primarily from the Black Sea by the opening of Bosphorus and Dardanelles Channels, during the post glacial sea-level rise, supplemented by major rivers that flow into the Aegean Sea. Continuous outflow of fresh water into the Aegean Sea provided a low salinity surface lid, preventing the ventilation of the deep water.

Benthic foraminiferal data shows a remarkable turn-over in the benthic assemblage indicative of very low dissolved oxygen levels, however, anoxic bottom water conditions did not occur. Stagnant deep water conditions in isolated depressions, together with the increased input of terrigenous organic matter and primary productivity, as indicated by pollen and dinocysts, subsequently resulted in the formation of sapropel level S1. The surface water temperature and salinity reached present-day values at ~6,400 yrBP, and very little change occurred since, despite the major deforestation onshore.

Sapropel S1 occurs as a 25-35 cm-thick black, weakly laminated muds in Aegean Sea cores. AMS dates show that S1 was deposited between 9600 and 6400 yrBP, about 1000 years after the last glacial-interglacial transition. S1 was deposited during a period of isotopically depleted (1.5-2.0 $^{0}/_{00}$) and relatively cool surface waters. Isotopic, microfaunal and floral data indicate a major reduction in surface waters salinity during the deposition of S1 and distribution maps of $\delta^{18}O_w$ show a northerly fresh water source. Relatively light $\delta^{13}C_{org}$ and high pollen and spore concentrations in S1 suggest increased influx of terrestrial organic carbon, probably supplied by major rivers draining into the northern Aegean Sea. Benthic foraminiferal data indicate high nutrient - low oxygen bottom waters during this time, and together with silt-sized hematite and various levels of manganese coatings suggest that during the deposition of S1 surface sediments were oxic. Visual and XRD identification of pyrite in S1 together with considerable enrichments in S, Cu, Zn, As, Ni, Cr and Fe suggested that subsurface conditions were sufficiently reducing in nature for SO_4^{2-} reduction to occur within S1, probably taking place by diffusion from surface oxic into subsurface anoxic sediments (Yaşar, 1994).

Palynomorphs in S1 show large increases in terrestrial pollen and spores, with the floral assemblage indicating significant northern European and minor African components. No significant increase in dinoflagellate cyst abundance in S1 suggests the absence of major upwelling in the region. These data suggested that the evolution of S1 in the Aegean Sea largely resulted from stagnation of the surface waters during the disintegration of the continental ice sheets, rather than an increase in primary productivity and the associated increase in the preservation of organic carbon on the sea floor (Yaşar, 1994).

4. Late Glacial to Holocene Paleo environmental Evolution of the Aegean Sea

4.1 Late glacial conditions

During the last glacial maxima, ~20,000 yrBP, the global sea-level was approximately 120 m below its present level (Fairbanks, 1989). Studies in the eastern Aegean Sea deltas show that the sea-level during the last phase of delta progradation prior to Holocene transgression was 110 to 125 m below its present position Aksu and

Piper (1983). Approximately 100 m lowering of sea-level dramatically altered the morphology and the water circulation patterns in the Aegean Sea. The continental shelves and banks and saddles between numerous islands were subareally exposed. For example, nearly the entire Aegean Volcanic Arc was exposed, leaving the narrow and shallow Ikaria Channel to form the only communication between the northern Aegean Sea and the eastern Mediterranean Sea. Southern portion of the Aegean Sea (Cretan Trough) was much less affected by the sea-level lowering, and several large and deep channels between the Peloponnesus, Crete, Rhodes and SW Turkey provided the communication with the eastern Mediterranean Sea.

Surface water circulation in the northern Aegean Sea was much reduced. The narrow and shallow Ikaria Channel prevented large-scale communication between the eastern Mediterranean and the northern Aegean Sea. This type of isolated basin morphology with little surface circulation is ideal for basin stagnation. However, elemental enrichment data and benthic foraminiferal data clearly show that during the late glacial period bottom waters were cool, but, well oxygenated. This is probably accomplished by bottom water formation along the northern periphery of the Aegean Sea, where cool subpolar waters were further chilled during the glacial winters, causing down welling, similar to that occurs in modern times. Furthermore the SST and salinity estimates suggest that the vertical thermal gradient was reduced, probably enhancing vertical convective mixing, thus oxygenation of bottom waters (Aksu *et al.,* 1995a,Aksu *et al.,* 1995b., Aksu *et al.,* 1995c)

Planktonic foraminiferal and dinoflagellate data from the late glacial sediments show that cold subpolar surface waters occupied the entire Aegean Sea between ca. 15,000 and 13,000 yrBP. There is no analogue for such a water mass in the present-day eastern Mediterranean Sea, however, best analogue can be found in the present-day subpolar North Atlantic.

4.2 Early Holocene conditions

Sea-level started to rise at ~18,000 yrBP from a glacial maximum low stand of ~-120 m, reaching ~-95 m by ~12,500 yrBP (Fairbanks, 1989). Between 12,500 and 9,000 yrBP, global sea-level curves show two pulses of rapid sea-level rise (Fairbanks, 1989), with the sea-level rising to -35 m by 9,000 yrBP. Present-day sill depths of the Straits of Bosphorus and Dardanelles suggest that the initial communication between the Black Sea and the Aegean Sea was established between 9,500 and 9,000 yrBP ; Stanley and Blanpied, 1980). This time period was also marked by the cessation of delta progradation along the shelf-edge encircling the Aegean Sea and by the rapid landward retreat of the deltas, associated with the post glacial transgression (Aksu *et al*., 1987 a, b).

Planktonic foraminiferal, dinoflagellate and coccolith data from the early Holocene sediments show that cold (subpolar) and low salinity surface waters occupied the entire Aegean Sea between ca. 9,600 and 6,400 yrBP. The $\delta^{18}O_w$ estimates show that this water mass was isotopically considerably depleted, suggesting ~1.0 - 1.5$^0/_{00}$ reductions in surface water salinities. The temporal and spatial distribution map of the $\delta^{18}O_w$ and salinity suggests a northerly source for this low salinity cold water mass. The timing of sapropel S1 deposition in the Aegean Sea basins, together with the glacio-eustatic sea-level standing at above the sill depths of Bosphorus and Dardanelles strongly suggest that initial excess fresh water overflow from the Black Sea was largely responsible for the depleted isotopic waters in the Aegean Sea.

During this time period the surface water circulation was dominated by the south flowing Black Sea surface waters, with little or no northward penetration of Mediterranean surface waters. Excess surface fresh water outflow formed a low salinity lid, enhanced vertical stratification, preventing vertical mixing and causing low oxygen bottom waters in isolated basins, as indicated by the benthic foraminiferal data.

4.3 Late Holocene conditions

During the late Holocene, between 6,400 to present, the sea-level continued to rise to reach its present level between 3,000 and 1,000 yrBP, establishing the present day morphology of the Aegean Sea. Planktonic foraminifera and dinoflagellate assemblages show that the surface water mass during the late Holocene was subtropical. Progressive warming in surface waters, from ca. 6,400 until present, is partly due to the amelioration of climate associated with the establishment of full interglacial conditions, but, is mostly the result of northward penetration of warmer eastern Mediterranean surface water into the Aegean Sea. Bottom water formation in northern Aegean Sea progressively replenished the bottom waters and caused the cessation of anaerobic conditions, and the establishment of the present-day marine conditions in the Aegean Sea.

5. Evolution of Lithofacies

5.1 Terrigenous sediments

Late glacial to Holocene sediments in the Aegean Sea cores consist primarily of an admixture of terrigenous clastics, calcareous and organic remains of micro fauna and flora, and volcanic ash. In Facies A, B and D some of this biogenic and terrigenous debris are partially cemented to form carbonate nodules and clasts; whereas in Facies C (sapropel S1) they are mostly uncemented. In deeper basinal cores, the overwhelming majority of the terrigenous debris is composed of clay-sized minerals. Except for abundant volcanic ash at certain stratigraphic levels, all facies examined in the cores showed little or no non-biogenic silt- and sand-sized terrigenous debris. Terrigenous sand and silt become important only in cores collected near the mouth of major rivers, such as south of the present-day mouth of the Meriç River, shelf cores along the eastern and northern Aegean Sea (Lykousis *et al.,* 1981; Aksu *et al.,* 1987 a, b; Piper and Perissoratis, 1991).

High rates of sedimentation and the overwhelming domination of the terrigenous particles by clay-sized minerals suggest that most sediments in the Aegean Sea are initially supplied by the major rivers of northern and eastern Aegean Sea. Paucity of sand and silt sized particles in the basinal sediments and their abundance in delta-dominated coastline (Aksu *et al.,* 1987 a, b) suggests that coarser clastics are mostly trapped in the shelves as prodelta sands and silts. Fine-grained (mainly clay-sized) terrigenous debris is further carried to offshore as sediment plumes associated with periods of heavier river discharge, and transported and dispersed by predominantly the surficial currents and to a lesser extent intermediate and deep currents. At present there are no major submarine channels in the region which prevent the transport of coarser terrigenous clastics into deep basins. Piper and Perissoratis (1991) showed that during periods of glacio-eustatic low-stands of sea-level small prodelta channels developed along the shelf-edge in northern Aegean Sea, feeding turbidite sedimentation in deeper basins. During the sea-level minima the coastline moved significantly closer to the shelf-edge, exposing considerable portions of the present-day shelves to subareal processes and favouring the delivery of terrigenous debris into deep-water regions (Yaşar, 1994).

5.2 Source of terrigenous sediments

The present-day mineralogical composition of the Aegean Sea sediments is a function of (i) changes in the source and amount of terrigenous input, (ii) syn- and post depositional carbonate cementation and (iii) syn- and post depositional changes due to redox conditions of sediments.

a) Facies A, B and D are characterized by high smectite and illite, low kaolinite and very low chlorite abundances. Smectites show high crystallinity, whereas illites exhibit low crystallinity. Increased ratios of smectite/illite and kaolinite/chlorite are probably a function of higher smectite and kaolinite and reciprocal lower illite and chlorite inputs, respectively.

b) Facies C (sapropel S1) is characterized by lower smectite, higher illite abundances, with notable increases in chlorite and a reciprocal decreases in kaolinite abundances. Lower smectite/illite and kaolinite/chlorite ratios are a function of increased supply of illite and chlorite and decreased supply of smectite and kaolinite during the deposition of this facies, respectively.Smectites in this facies show poor crystallinity, whereas illites show high crystallinity

The mineralogical data suggest that except for Facies C, the late-glacial to Holocene sediments (Facies A, B and D) in the Aegean Sea cores are derived from petrologically similar sources. Clay mineralogical data alone do not allow an immediate and unambiguous distinction amongst these sources. The mineralogy of Facies C suggests a noticeably different petrological source(s). Several potential sources exist for the clay-mineral assemblages observed in the cores (Aksu *et al.,* 1995a, Aksu *et al.,* 1995b, Aksu *et al.,* 1995c).

In the eastern Mediterranean smectite is primarily of North African origin (Stanley and Liyanage, 1986; Emelyanov and Shimkus, 1986). However, present-day shelf sediments off major deltas in the Aegean Sea also include significant quantities of smectite. For example, between 32 and 45% clay fraction of shelf sediments offshore the rivers Aliakmon, Axios and Pinios in the northern Aegean Sea and Gediz, Bakırçay, Büyük Menderes and Küçük Menderes in eastern Aegean Sea is composed of smectite, suggesting abundant local sources in the landmass surrounding the Aegean Sea. Furthermore, smectite inputs from the Nile River are expected to be primarily dispersed along the easternmost segment of the Mediterranean Sea, along the coast of Israel, Lebanon and Syria, following the prevailing surface currents. Therefore, large contributions of smectite from the Nile river seems unlikely. The distribution of smectite in the Aegean Sea strongly implies a northerly source, possibly supplied by the major rivers draining into the northern Aegean Sea.

Kaolinite in the eastern Mediterranean is also a clay mineral of north African origin (Emelyanov and Shimkus, 1986). Previous studies have clearly documented the relationship of kaolinite with aeolian dusts from Saharan origin (Chamley, 1988; Chamley *et al.,* 1990). The distribution map of kaolinite clearly shows higher concentration of this mineral in southern Aegean Sea, sharply decreasing northwards. This trend further suggests that although smaller quantities of kaolinite may have been supplied by major rivers, a North African Aeolian input cannot be excluded.

In high latitudes where hydrolysis is limited, chlorite is abundant, resulting from the erosion of metamorphic and plutonic rocks. Although chlorite-bearing rocks are abundant in the landmass surrounding the Aegean Sea, clay-sized chlorite is limited in the Aegean Sea sediments, reflecting the efficiency of continental hydrolysis. Highest concentrations of chlorite (~13%) are found in the prodelta muds off the Büyük Menderes River, which drains the large metamorphic Menderes Massif. Chlorite is more abundant in Black Sea surface sediments. Except for the mouths of the Danube and Dnestre rivers, the kaolinite/chlorite ratio of the Black Sea surface sediments are very low (0.4-0.9), compared to 1.3-2.8 in the surface sediments in the Aegean Sea. Higher proportions of chlorite input is expected during the glacial periods where chemical weathering of chlorite is much reduced.

The provenance of illite in general, low-crystallinity illite, in particular is probably associated with the sedimentary rocks surrounding the Aegean Sea. Poor crystallinity illite is also a major constituent of the wind-borne dusts of North African origin (Tomadin and Lenaz, 1989). In prodelta muds off the Büyük Menderes delta well-crystallized illite is found in association with high chlorite abundances. The distribution maps of illite is similar to that of smectite, showing higher percentages of this mineral in norther Aegean Sea and suggesting that illite is predominantly supplied from a northerly source.

Similar clay mineralogical changes are also observed in the upper Quaternary hemipelagic sediments of the eastern Mediterranean between sapropel and non-sapropel deposits (Cita *et al.,* 1977; Dominik and Stoffers, 1978; Chamley, 1989; Tomadin and Landuzzin, 1991). The causes of the remarkable clay mineralogical changes recorded between sapropel S1 (Facies C) and non sapropel sediments (Facies A, B and D) can be explained by (i) a drastic change in the type of terrigenous input or (ii) chemical degradation under the strongly reducing conditions during the deposition of sapropel S1 (Yaşar, 1994).

Significant increases in chlorite and well-crystallized illite observed in Facies C probably represent an increased supply of these minerals into the Aegean Sea between ~9,600 and 6,400 yrBP, associated with the deglaciation of the northern European and Siberian ice sheets. Major rivers flowing into the northern Aegean Sea drain large regions of central and southern Europe. These areas are located adjacent to alpine glaciers and at the catchment of the northern European ice sheets. Pluvial conditions which prevailed during the last glacial to interglacial transition throughout southeastern Europe and northern Mediterranean are more conducive for intense hydrolysis on land, thus the destruction of chlorites and illites (Chamley, 1989). The clay mineralogical data suggest a prominent northern source during the deposition of Facies C, although local sources such as the Menderes Massif and Rodop Massif cannot be excluded.

The notable reduction of smectites in Facies C may be partly the result of post-depositional degradation of this mineral in strongly reducing conditions. Although small in percentage, irregular mixed-layer clays, particularly chlorite-smectite and illite-smectite, observed in this facies, suggest the presence of subsurface degradation of the clay assemblage. Some of the high crystallinity illite may also be the result of moderate to strong submarine degradation (Chamley, 1989).

5.3 Carbonate sediments and cementation

The carbonate layers, clasts and nodules cemented by magnesium calcite indicate that pore waters at and near the seafloor are supersaturated with respect to magnesium calcite. Pteropods in deep sea sediments are commonly used as an index of the saturation state of the overlying ocean water relative to skeletal aragonite (Berner, 1977; Berger, 1977). Pteropods and silt- and clay-sized aragonite clearly show that the late glacial to Holocene sediments in the Aegean Sea were saturated with respect to aragonite.

The $MgCO_3$ content of Mg-calcite precipitated from seawater is related to the temperature and carbonate ion concentrations of the environment (MacKenzie *et al.,* 1983). The amount of $MgCO_3$ in magnesium calcite increases with; (1) increasing temperature (Mucci and Morse, 1983), (2) increasing carbonate ion concentration (Given and Wilkinson, 1985) and (3) Mg/Ca ratio of the fluid (Mucci and Morse, 1983). Mg/Ca ratios are not sufficiently variable in the modern ocean to account for the observed trends in mineralogy, so it appears that temperature and carbonate ion concentration are most important.

At present Aegean Sea is a small basin with restricted anti-estuarine circulation. During the early Holocene sea-level rise (ca. 9,600 to 6,400 yrBP) the surface circulation was primarily driven by the excess fresh water input into the Aegean Sea from (i) Black Sea via the opening of the Bosphorus and Dardanelles Channels and (ii) major rivers draining into the Aegean Sea. During this period (deposition of Facies C, sapropel S1) the Aegean Sea water masses exhibit strong vertical stratification, with colder water masses occupying the deep basins. Examination of the Aegean Sea core data showed that the partially to well cemented clasts and nodules are generally restricted to hemipelagic sediments deposited during late glacial (Facies D) and late Holocene periods (Facies A and B).

Similar magnesium calcite lutite layers and nodules in the Mediterranean are interpreted to have formed from elevated temperature and salinity waters during both glacial periods and interglacial periods when thermohaline circulation was active, but not during transition periods when abundant freshwater runoff led to a stratified water column (Milliman and Müller, 1973; Aksu *et al.,* 1995b; Yaşar *et al.,* 1998).

6. Evolution of Sapropel S1

The development of the most recent sapropel layer (S1) in the Aegean Sea is evaluated in the following steps: (i) timing of sapropel formation and its relationship to the climatic evolution of the eastern Mediterranean, (ii) source of organic carbon, (iii) pale oceanographic conditions at the sea surface associated with the transition from the last glacial to Holocene, (iv) bottom water conditions during the deposition of the sapropel layer, (v) subbottom anoxic conditions that lead to significant metal enrichments. Finally, the controversy (anoxia versus high productivity) on the evolution of sapropels is addressed and a synthesis was presented.

6.1 Timing of sapropel formation

The available radiocarbon dates and the volcanic ash layers suggest that the sapropel S1 was deposited from 9,700 to 6,600 yrBP in the North Aegean Trough, from 9,800 to 6,400 yrBP in the North Skiros Basin, from 9,600 to 6,500 yrBP in the South Skiros Basin, from 9,500 to 6,300 yrBP in the South Ikaria Basin and from 9,400 to 6,400 yrBP in the Cretan Trough. It is clear that within the limitations of the data the deposition of the sapropel S1 in the Aegean Sea was a basin-wide phenomenon, occurring essentially synchronously, starting at ~9,600 yrBP and ending at ~6,400 yrBP (Yaşar, 1994., Aksu *et al*., 1995a, Aksu *et al*, 1999,Aksu *et al.,* 2008)

6.2 Source of organic matter in the Aegean Sea

Temporal and geographical distribution of the $\delta^{13}C_{org}$ show that, in general, heavier $\delta^{13}C_{org}$ values are found in the northern Aegean Sea distinctly becomes lighter towards the south. This southward enrichment in $\delta^{13}C_{org}$ can be attributed to larger influxes of terrestrial organic carbon supplied by several major rivers draining into the northern Aegean Sea. The absolute $\delta^{13}C_{org}$ values in the sapropel layer S1 (Facies C) show remarkable similarities, ranging between -23.5 and -24.1 $^0/_{00}$. These values are significantly lighter than those recorded in surface sediments, suggesting higher contributions of terrestrial organic carbon during the deposition of sapropel S1. It is difficult to determine the terrestrial and marine end-member carbon isotopic compositions in the Aegean Sea. However, assuming that the isotopic composition of the organic carbon supplied to the Aegean Sea from the surrounding land mass is approximately -27 $^0/_{00}$ (average temperate zone C_3-type plants; (Deines, 1980) and that the average isotopic composition of the marine phyto and zooplankton in the Eastern Mediterranean is approximately -22 $^0/_{00}$ (Fontugne, 1983), the $\delta^{13}C_{org}$ values in the Aegean Sea cores would represent sedimentary facies containing a varying mixture of terrestrial and marine organic carbon sources. The depleted $\delta^{13}C_{org}$ values recorded at the base of the cores ranging from -25.4 $^0/_{00}$ in core 3 (North Aegean Trough) to -24.5 $^0/_{00}$ in core 5 (South Ikaria Basin) probably represent higher contribution of terrestrial organic carbon into the Aegean Sea during these times. Heavier $\delta^{13}C_{org}$ values recorded in the core tops ranging from -23.7 in core 3 to -22.5 in core 5 are very close to the average isotopic signature of the marine plankton, therefore, probably reflect reduced contribution of terrestrial organic carbon into the Aegean Sea at present.

6.3 Surface water conditions

The oxygen isotopic data show that the environmental conditions leading to the initiation of sapropel S1 in the Aegean Sea developed immediately following the rapid transition from heavy to light isotopic values, associated with the last glacial-interglacial transition (Yaşar, 1994). This association of sapropel S1 with the last deglaciation has been previously documented in the eastern Mediterranean Sea (e.g. Vergnaud-Grazzini, *et al.,* 1977; Williams and Thunell, 1979; Rossignol-Strick, 1985, Yaşar, 1996). Estimates of the $\delta^{18}O_w$ show that during the deposition of sapropel S1 the isotopic composition of the Aegean Sea surface waters was approximately 2.0 to 2.5 $^0/_{00}$ more depleted than its present-day value. Similarly SSS estimates based on planktonic foraminiferal transfer function indicate that during the deposition of sapropel S1 the surface water salinity was also reduced by approximately 1.0 to 1.5 $^0/_{00}$. This remarkable depletion strongly argues for a major salinity reduction in surface waters. The temporal and geographical distribution of surface water $\delta^{18}O_w$ and salinity estimates show that an apparent gradient has developed in the Aegean Sea between ~9,600 and 6,400 yrBP, with $\delta^{18}O_w$ and SSS values becoming progressively more depleted northwards. Reduction in surface water salinities is further suggested by the coccolith and planktonic foraminiferal data. The distribution patterns of living coccolithophores in the Mediterranean Sea clearly show that highest frequencies of *G.oceanica* and small gephyrocapsids in the water column occur in regions of salinity minima (37.0 - 37.5 $^0/_{00}$), with values of 1.5 - 2.0 $^0/_{00}$ lower than the normal salinity values of the eastern Mediterranean surface water (Knappertsbusch, 1993). Significant occurrences of *G.oceanica*, *G.aperta* and *G.muellerae* within the sapropel S1 in the Aegean Sea cores suggest reduction of surface water salinities in the region. The planktonic foraminiferal assemblage within the sapropel intervals in the Aegean Sea cores include, amongst others, significant occurrences of *O.universa*, *Gr.scitula* and minor occurrences of *N.dutertrei*. This assemblage has been identified as the "sapropel fauna" in the Strait of Sicily and correlated with the incursions of low salinity surface waters in the regions (Muerdter, 1984).

6.4 Bottom water conditions

Benthic foraminiferal and sediment elemental enrichment data are used to infer conditions that prevailed in the Aegean Sea basins during the deposition of the sapropel layer S1 (Yaşar, 1994). It is important to note that although the species diversity was radically reduced and the total benthic foraminiferal counts were much lower in at least 3 of the 4 cores studied, non of the samples analyzed from the sapropel S1 were devoid of benthic foraminifera. The benthic fauna in sapropel S1 is dominated by *Globobulimina affinis*, *G.pseudospinescens* and *Chilostomella mediterranensis* with lesser, but significant occurrences of *Bolivina alata*, *B.attica*, *Bulemina clava* and *U.peregrina curticosta*. Of this benthic assemblage *G.affinis*, *G.pseudospinescens* and *C.mediterranensis* are previously found in association with sapropels from the eastern Mediterranean Sea (Mullineaux and Lohmann, 1981) and the Strait of Sicily (Ross and Kennett, 1984), and are reported to co-occur with Bolivina species in several sapropels (Cita and Podenzani, 1980; Herman, 1981). *G.affinis* is also reported in large abundances from the surface sediments of the eastern North Aegean Trough (Mullineaux and Lohmann, 1981). *G.affinis*, *G.pseudospinescens*, *C.mediterranensis* and Bolivina species have been documented to occur in large abundances in low-oxygen bottom water conditions (Mullineaux and Lohmann, 1981; Ross and Kennett, 1984). Several Globobulimina species have been argued to be a deep-dwelling planktonic form, being able to float above the deepest anoxic bottom waters. Even if this is the case, Aegean Sea sapropel layer S1 includes several other benthic foraminiferal species.

By definition anoxia requires that there is no oxygen-related reaction in the bottom waters, and the presence of a reducing environment with varying levels of H_2S concentrations in the bottom waters. In previous studies sapropels are often equated with bottom water anoxia (Olausson, 1961), and in several cases the term is used as synonymous to low-oxygen bottom water conditions. In the Aegean Sea cores sediments from S1 are not devoid of benthic foraminifera. Because benthic foraminifera cannot live within an anoxic environment, the presence of benthic foraminifera in the sapropel layers indicates that bottom water anoxia did not prevail within the basin of the Aegean Sea during the deposition of S1. This might be partially due to shallower water depth of the Aegean Sea basins compared to that in the eastern Mediterranean Sea. However, the specific benthic foraminiferal fauna indicates that low-oxygen bottom water masses occupied the basins during the deposition of sapropel S1.

6.5 Subbottom anoxic conditions

Sapropel layers in the Aegean Sea cores show significant enrichments in S, Mn, chalcophile elements such as Cu, As, Ni and Zn, and siderophile elements such as Cr, Ti and Fe (Yaşar, 1994). Close association of these elements with sapropels does not necessarily indicate that elemental enrichments are associated with TOC. Sapropels include lower carbonate concentrations and part of the observed enrichment may be due to closure effect. Several elements, such as Cu, Zn, Ni, As and Cr show high affinity for sulphides and are enriched in sulphide-rich sapropels. Furthermore, elements become enriched in sapropels during the early diagenesis by the mobilization of primarily Fe and Mn and other elements as a result of migrating redox front (Pruysers *et al*., 1991). Sulphur is enriched in sapropel S1 in all cores studied. Identification of pyrite in the clay- and silt-sized fractions as well as visual identifications as fillings in foraminiferal shells and worm borrows strongly suggest that pyrite is the main S-bearing phase in the Aegean Sea sapropel S1. Chromium and chalcophile elements, such as Cu, As, Zn and Ni are also enriched in sapropels; these elements are known to have high affinity for humic substances (Calvert and Pedersen, 1993) as well as high affinity for sulphides (Moore *et al.,* 1988) and therefore enriched in sulphide-rich sapropels in the eastern Mediterranean. A near linear relationship observed between TOC and S in the Aegean Sea sediments suggest that an intrinsic mass balance must exist between the organic carbon oxidised by bacterial sulphate reduction and the amount of the bacterially produced sulphur converted into pyrite (Berner, 1984). Sulphate reduction and subsequent iron sulphide formation is an important process in the enrichment of minor and trace elements in sediments (Emerson *et al.,* 1983). Sulphate reduction can take place at the sediment-water interface or anoxic-oxic seawater interface, such as that observed in the recent anoxic Tyro and Bannock Basins of the Eastern Mediterranean (Henneke *et al.,* 1991). It can also occur in oxic basins at a variable depth below the sediment-water interface where microbial utilization of oxygen, nitrate and Fe and Mn oxyhydroxides produce conditions which are sufficiently reduced for bacterial sulphate reduction and subsequent formation H_2S (Calvert, 1990). Visual and XRD identification of pyrite in the sapropel samples together with considerable enrichments in minor and trace elements suggest that conditions were sufficiently reducing in nature for SO_4^{2-} reduction to occur in the sapropel deposits. Part of the enrichments in Cu, Zn, As, Ni and Fe can be explained by SO_4^{2-} reduction and subsequent FeS_x and other highly insoluble sulphide formation in the presence of H_2S. In anoxic basins, such as the Black Sea, dissolved concentrations of Cu, Zn, Ni and Fe are found to decrease by several factors from the upper oxic to the underlying anoxic water masses: these dramatic decreases are interpreted to occur as the result of precipitation of respective solid sulphides in the presence of H_2S in the anoxic waters (Landing and Lewis, 1991).

Strong enrichments of Mn is found at the base of S1, however, a significant depletion of Mn is observed throughout S1 in all four cores studied. Except in core 19, where the Mn and Fe maxima co-occur, in the rest of the cores Mn maxima occurs immediately below the Fe maxima. Oxidation of Fe^{2+} by Mn-oxyhydroxides in the region of Mn depletion may result in enrichment in Fe-oxyhydroxides, which would provide additional explanation for Fe enrichments in the sapropel S1. Depletion of Mn in sapropel S1 in the eastern Mediterranean has been reported (Pruysers *et al.,* 1991) and interpreted as the result of oxidation of organic matter by Mn-oxyhydroxides. Calvert and Pedersen (1993) showed that Mn is generally depleted in modern sediments accumulating under anoxic bottom waters, but it is enriched in oxic deep sea sediments and suggested that Mn enrichments in sediments can be used as a reliable indicator of sedimentation under oxygenated bottom water conditions.

In summary, the presence of Mn enrichments in Facies A and D and the absence of enrichments in Cu, Zn, As, Ni, Cr and Fe in these sediments together with the presence of silt-sized hematite collectively suggest that these sediments were deposited under oxygenated bottom water conditions (Yaşar, 1994). The presence of considerable enrichments in Cu, Zn, As, Ni, Cr and Fe in the sapropels may be interpreted as sedimentation within anoxic waters, where surface sediments were in contact with sulphidic waters. However, the presence of benthic foraminifera in the sapropel samples strongly suggests that the surface sediments during the deposition of S1 were *sensu stricto*, oxic; although the benthic assemblage suggests very low dissolved oxygen level of the bottom water mass. The combined faunal and elemental chemistry data suggest that elemental enrichment took place by diffusion into subsurface anoxic sediments.

The presence of low oxygen bottom waters and increased terrigenous organic flux into the Aegean Sea provided the necessary conditions for increased TOC accumulation and preservation. Subsurface oxidation of TOC provided the necessary conditions for subsequent sulphate reduction, thus, subsurface anoxia.

6.6 Anoxia - low oxygen bottom waters versus high productivity

Sapropel layers in the Aegean Sea cores also show significant enrichments in Ba. The association of elevated Ba concentrations and high fertility has long been recognized (Dymond, 1985; Schmitz, 1987), especially in areas dominated by siliceous microfossils, in areas of high marine flagellate production and in sapropel deposits in Black Sea (Calvert, 1990), where no apparent mechanism could be identified for the observed high Ba concentrations in the sediments. However, recent work from the Bannock Basin (eastern Mediterranean) suggested that the interpretation of Ba as a paleoproductivity indicator is not unequivocal and that the Ba precipitation may be caused mainly by the rise in pore water sulphate concentration following the oxidisation of sulphides following the deposition of sapropel (Van Os *et al.,* 1991). Therefore, high concentrations of Ba in sapropel S1 may be interpreted as indication of increased productivity or may be related to redox-related cycling (Yaşar, 1994; Aksu *et al.,* 2008).

6.7 Synthesis - evolution of Sapropel S1

During the glacial maxima, some 20,000 yrBP the sea-level was ~115 m below its present level (Aksu *et al.,* 1987 a, b; Yaşar, 1994), eliminating the communication of the Black Sea and the Aegean Sea. During this time period the Marmara Sea temporarily became a lake (Stanley and Blanpied, 1980). A large proportion of the continental shelves, including several shallow channels that presently form the Aegean Volcanic Arc were sub-aerially exposed, reducing the communication of the Mediterranean and Aegean Sea through the narrow Ikaria Channel. North Aegean Trough, North and South Skiros and North Ikaria Basins collectively formed a large, literally land-lock basins, referred to as the North Aegean Basin. To the south of the Ikaria Channel another semi-enclosed basin developed, communicating with the Mediterranean Sea through the Kithria, Crete, Kasos, Karpathos and Rodhos Channels. Micropaleontological data suggest that during this period subpolar to transitional water masses occupied the North and South Aegean Sea. Elemental enrichment and benthic foraminiferal data suggested that bottom waters were fully oxygenated. Clay and silt mineralogical data suggested supply of terrigenous debris from the surrounding land mass.

Global glacio-eustatic sea-level curve (Fairbanks, 1989) suggest that the post glacial sea-level rise in the eastern Mediterranean started at ~14,000 yrBP from a glacial maximum low of ~-115 m. Between ~12,000 and 9,500 yrBP the sea level rose from ~-

100 m to ~-50 m. This time period was also marked by the cessation of delta progradation along the shelf-edge encircling the Aegean Sea and by the rapid landward retreat of the deltas, associated with the post glacial transgression (Aksu *et al.,* 1987 a, b). The Straits of Bosphorus and Dardanelles (present-day depths of 30-40 m and 50-60 m, respectively), and a sea-level at -50 m allowed the initial communication between the Black Sea and the Aegean Sea (Stanley and Blanpied, 1980). The temporal and spatial distribution of the $\delta^{18}O_w$, the timing of sapropel S1 deposition in the Aegean Sea basins, together with the predicted glacio-eustatic sea-level stand at -50 m strongly suggest that the initial excess fresh water overflow from the Black Sea may be largely responsible for the depleted isotopic waters in the Aegean Sea (Yaşar, 1994;Yaşar, 1998., Aksu *et al.,* 2008).

7. Conclusions

-Four hemipelagic lithofacies are identified in the late glacial to Holocene sediments in the Aegean Sea. These lithofacies are silty-clay and clay in texture and include an admixture of (i) loose terrigenous sediments directly supplied from the adjacent landmass, (ii) gravel- to sand-sized cemented carbonate clasts and nodules, (iii) sand- to silt-sized air-born volcanic debris and (iv) various biogenic remains.

-Sediment dispersal is mainly controlled by the fluvial discharge rates, the sea-level variations, which determine the proximity of the Aegean basins to river mouths and the prevailing oceanographic conditions in the Aegean Sea.

-Cemented carbonate clasts and nodules occur throughout the cores except within the sapropel layer S1, and are composed of carbonate, in the form of 10 to 14 mole % magnesium calcite. They are well- to friably-cemented mottled to peloidal micrite or microcrystalline inter-granular cement between terrigenous and bioclastic debris,

-Micropaleontological data show that aragonite, in the form of pteropods and microcrystalline aragonite is present throughout the cores, and together with these precipitates, both in surface and subsurface sediments, indicate that shallow pore waters in the Aegean Sea are now and have been for at last 10,000 years, saturated to supersaturated with respect to both aragonite and magnesium calcite.

-XRD results show that Facies C (sapropel S1) is characterized by lower smectite, higher illite abundances, with notable increases in chlorite and a reciprocal decrease in kaolinite abundances. Lower smectite/illite and kaolinite/chlorite ratios are a function of increased supply of illite and chlorite and decreased supply of smectite and kaolinite during the deposition of this facies.

-Planktonic foraminiferal, coccolith and dinoflagellate data show that the last glacial to Holocene transition in the Aegean Sea is associated with a considerable warming in surface water temperatures: SST estimates show between 50C and 100C increase in winter surface temperature from ca 14,000 to 9,600 yrBP.

-Surface salinity estimates derived from oxygen isotopic and planktonic transfer function data indicate that this warming was also associated with a 1.0 to 1.5 $^{0}/_{00}$ salinity reduction throughout the Aegean Sea.

-Surface salinity values remained ~1.0 $^{0}/_{00}$ lower than that observed today for approximately 3,000 years (ca. 9,600 to 6,400 yrBP),

-The early Holocene excess fresh water originated from rapid melting of the northern European and Siberian ice sheets, supplied primarily from the Black Sea by the opening of Bosphorus and Dardanelles Channels, during the post glacial sea-level rise, supplemented by major rivers that flow into the Aegean Sea.

-Continuous outflow of fresh water into the Aegean Sea provided a low salinity surface lid, preventing the ventilation of the deep water. Benthic foraminiferal data shows a remarkable turn-over in the benthic assemblage indicative of very low dissolved oxygen levels. Stagnant deep water conditions in isolated depressions, together with the increased input of terrigenous organic matter and primary productivity, as indicated by pollen and dinocysts, subsequently resulted in the formation of sapropel level S1.

-The surface water temperature and salinity reached present-day values at ~6,400 yrBP, and very little change in Aegean Sea paleoclimate and oceanography has been observed since, despite the major deforestation onshore as reflected in the pollen assemblage of Facies A.

Sapropel S1 is identified in the Aegean Sea cores a single 25-35 cm-thick dark brownish green/blackish green, weakly laminated silty/clayey mud layer. It is characterized by 2-6% TOC and much lower total carbonate values.

-AMS dates on foraminiferal/pteropod shells showed that S1 in the Aegean Sea are formed between 9,600 and 6,400 yrBP, immediately following the oxygen isotopic stage 2 to 1 transition.

-SST and $\delta^{18}O_w$ estimates showed that S1 was deposited during a period where the surface waters were substantially cooler, with the isotopic composition of the surface waters ~1.5 to 2.0 $^{0}/_{00}$ more depleted than its present-day value. The remarkable depletion in $\delta^{18}O_w$ is interpreted as major salinity reduction in surface waters. Reduced surface salinities are also suggested by the planktonic foraminiferal and coccolith data. The temporal and spatial distribution of surface water $\delta^{18}O_w$ values showed that an apparent gradient has developed in the Aegean Sea between ~9,600 and 6,400 yrBP, with $\delta^{18}O_w$ values progressively becoming depleted northward.

-The isotopic composition of the TOC showed that $\delta^{13}C_{org}$ values are heavy at surface, progressively becoming lighter with depth. Temporal and geographical distribution of the $\delta^{13}C_{org}$ showed that heavier $\delta^{13}C_{org}$ values are found in the northern Aegean Sea, distinctly becoming lighter towards the south, reflecting larger influxes of terrestrial organic carbon supplied by several major rivers draining into the northern Aegean Sea. Significantly lighter $\delta^{13}C_{org}$ values in S1 suggested higher contributions of terrestrial organic carbon during the deposition of sapropel S1.

-The benthic foraminiferal fauna in sapropel S1 is characterised by a very low diversity assemblage distinctive of high nutrient and low oxygen environment. The presence of considerable enrichments in Cu, Zn, As, Ni, Cr and Fe in the sapropels may be interpreted as sedimentation within anoxic waters, where surface sediments were in contact with sulphide-enriched waters. However, the presence of benthic foraminifera in the sapropel samples suggested that the surface sediments during the deposition of S1 were, *sensu stricto*, oxic; the observed elemental enrichments took place by diffusion into subsurface anoxic sediments.

-The sapropel layers included remarkable increases in terrestrial pollen and spore abundances, where the floral assemblage includes a significant northern European component and a varying, but, minor African component.

-Clay and silt-sized pyrite is one of the most significant constituents of S1. Pyrite is also microscopically identified as fillings in foraminifera or replacements of worm tubes. Although small in percentage, the presence of silt-sized hematite further suggested that the bottom waters during the sapropel deposition were not anoxic in the Aegean Sea basins. The clay fraction of S1 is characterized by a noticeable decrease in smectite and kaolinite and reciprocal increases in illite and chlorite and quartz.

-The overall data suggest that the evolution of the sapropel layer S1 in the Aegean Sea is caused by the stagnation of the surface waters during the disintegration of the continental ice sheets, rather than an increase in primary productivity and the associated increase in the preservation of organic carbon on the sea floor.

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GENERAL TECTONICS OF THE AEGEAN SEA AREA AND GEOPHYSICAL SIGNATURES

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1. Introduction

The Aegean Sea is surrounded between the coasts of mainland Greece, the coasts of western Turkey and Crete. Morphologically speaking, the Aegean constitutes a relatively shallow sea, since it comes from the submergence of Aegeis land. Its seabed though is corrugated by several trenches, some parts of which have a quite long depth, while this complex coastline results in the creation of many small and big bays, capes and natural ports (Figure 1). The geographers and the geologists have divided the Aegean Sea in three parts following the morphology of the coasts, the position of the islands and the formation of the seabed; North, Central and South Aegean. The borders of South Aegean is the northern imaginary line from Sounion and Kafireas up to Samos and the coasts of Asia Minor and the southern borders of the sea are from Laconia, Kythera and Crete up to cape Marmaris in Asia Minor. The South Aegean is considered the most important part of the Aegean Sea, and there are located the most of the islands. The two big complexes, meaning the Cyclades and the Dodecanese, the islands of Ikaria, Samos and Fournoi on the east and on the west the islands of the Saronic Gulf near Attica and the Argolic Gulf in Peloponnese. The South Aegean is divided in smaller seas, the Myrtoan Sea on the west, the Cretan Sea on the south and the Icarian Sea and the Karpathian Sea on the east.

The current geomorphological condition of the Aegean is the result of three main parameters: the tectonism, the volcanic activity and the eustatism (i.e. the rise and fall of the sea level). The history of the Aegean begins about 35 million years ago, when, during Oligocene, land emerged from the sea for the first time. This orogenesis, which was part of the overall Alpine orogenesis in southern Europe, was completed during the late Oligocene (approximately 25 million years ago) and the result was the creation of an extensive mountain land area covering the entire South Aegean, joining current Peloponnese and the lower part of mainland Greece with Crete and Asia Minor. The single land covering the Aegean during that period was called Aegeis.

The islands of the Aegean actually started being formed during the Middle to Upper Miocene, i.e. 12 to 11 million years ago, when the sea began to penetrate the hitherto single mass of Aegeis, slowly fragmenting the single land mass of Aegeis. Numerous and complex tectonic movements that took place during the end of the

Miocene (6 to 5.3 million years ago) among others, caused further fragmentation of the land, forming islands that constituted the current Cyclades. During the Pleistocene (1.8 to 0.9 million years ago) the main causes of the change in the Aegean region's geography was eustatism and tectonism. The eustatic moves, i.e. the rise and fall of the sea level, due to the alternation of the glacial and interglacial periods, were causing expansion or reduction of the land areas and change of the land connections between them. Finally, during the Holocene, with the end of the last glacial period, the sea level rises and the Aegean region gradually acquires its current geography. The Eastern Aegean islands are cut off from Asia Minor and the Cyclades islands are permanently isolated from one another.

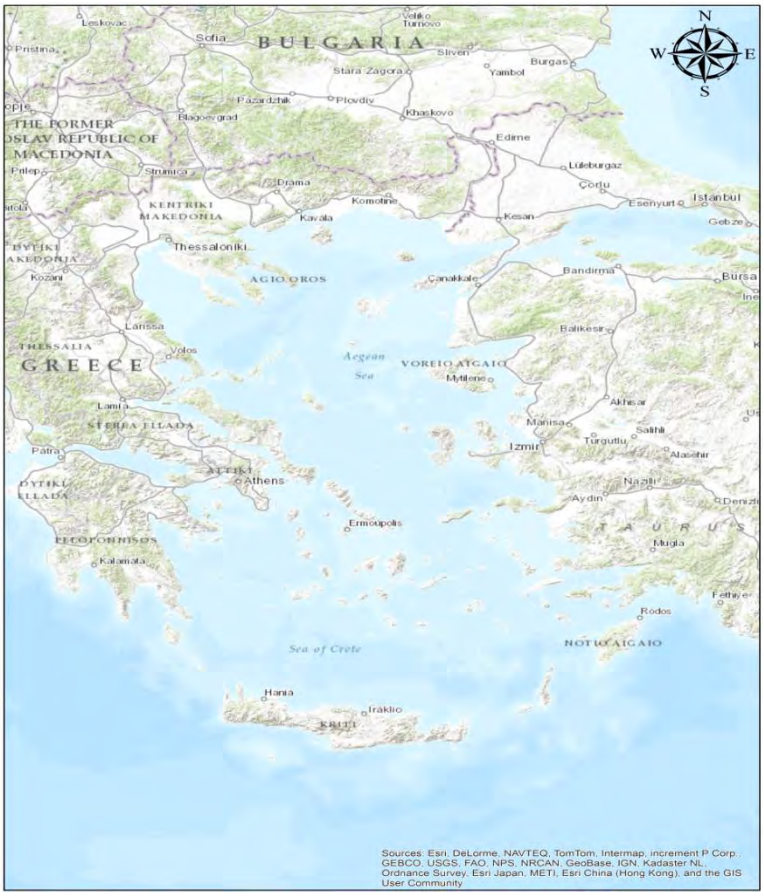

Figure 1. Geographic map of the Aegean Sea (from ArcGIS - ESRI)

2. General Tectonic Framework of the Alp-Himalayan Orogenic System

The Eastern Mediterranean and the Middle East make up the southern boundary of the Tethys Ocean for the last 200 Ma by the disintegration of the Pangaea and closure of the Tethys Ocean (Figure 1). It covers the structures: Hellenic and Cyprus arcs, Eastern Anatolian Fault Zone, Bitlis Suture Zone and Zagros Mountains. The northern boundary of the Tethys Ocean is made up the Black Sea and the Caspian Sea, and it extends up to Po valley towards the west (Pontides, Caucasus). Between these two zones the Alp-Himalayan orogenic belt is situated where the Balkan, Anatolia and the Iran plateaus are placed as the remnants of the lost Ocean of the Tethys (Figure 2).

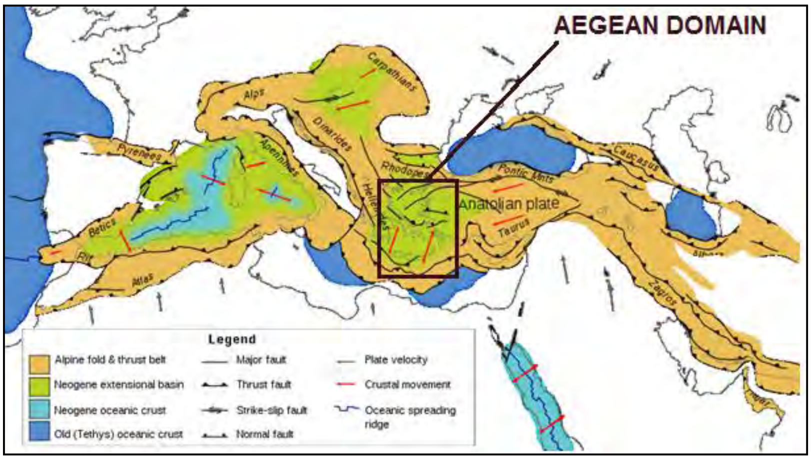

Figure 2. Tectonic framework of the Mediterranean domain (the Aegean domain is the Neogene extensional basin formation) (Wouldpower, 2009).

The active tectonics of the eastern Mediterranean is the consequences of the convergence between the Africa, Arabian plates in the south and the Eurasian plate in the north. These plates act as converging jaws of vise forming a crustal mosaic in between. The active crustal deformation pattern reveals two N-S trending maximum compression or crustal shortening syntaxes': (i) the eastern Black Sea and the Arabian plate, (ii) the western Black Sea and the Isparta Angle. The area of the Aegean Sea and western Turkey is mainly an extensional graben area within this Alp-Himalayan orogenic system.

3. Tectonic Framework of the Aegean Domain

The convergent plate margins of the eastern Mediterranean Sea represent an excellent natural laboratory for building our understanding of the transition in young mountain belts from ocean crust, through agglomerating arc systems with long histories of oceanic closure, to the formation of continental hinterlands. Continental crust forms from structurally thickened remnants of oceanic crust and overlying sediments, which are then invaded by arc magmatism. Understanding this process is a first order problem of lithospheric dynamics. The transition in young mountain belts, from ocean crust through the agglomeration of arc systems with long histories of oceanic closures, to a continental hinterland is well exemplified by the plate margin in the eastern Mediterranean. Therefore the Alpine-Himalayan zone is the most interesting part of the world. The Aegean Sea domain is in between the Hellenides in the west and the Anatolian plate in the east within the Alpine-Himalayan orogenic belt. The Aegean region is tectonically a complex area characterized mainly by the subduction of African oceanic lithosphere beneath the Aegean continental lithosphere including extensional sub basins and mantle driven block rotations (Figure 3). Its southern edge is a subduction zone south of Crete, where the African Plate is being swept under the Aegean Sea Plate. To the north is the Eurasian Plate, which is a divergent boundary responsible for the formation of the Gulf of Corinth. The southern part of the Aegean has also been deformed by normal faulting but is now relatively inactive. In northwestern Greece and Albania there is a band of thrusting near the western coasts adjacent to a band of normal faulting further east. The pre-Miocene geology of the islands in the Aegean closely resembles that of Greece and Turkey, yet seismic refraction shows that the crust is now only about 30 km thick beneath the southern part of the sea, compared with nearly 50 km beneath Greece and western Turkey. These observations suggest that the Aegean has been stretched by a factor of two since the Miocene. This stretching can account for the high heat flow. The sinking slab produced by subduction along the Hellenic Arc may maintain the motions, though the geometry and widespread nature of the normal faulting is not easily explained. The motions in northwestern Greece and Albania cannot be driven in the same way because no slab exists in the area. They may be maintained by blobs of cold mantle detaching from the lower half of the lithosphere, produced by a thermal instability when the lithosphere is thickened by thrusting. Hence generation and destruction of the lower part of the lithosphere may occur beneath deforming continental crust without the production of any oceanic crust.

4. Seismicity and Active Deformation in the Eastern Mediterranean

The tectonic framework of the eastern Mediterranean is dominated by the collision McKenzie, of the Arabian and African plates with Eurasia (McKenzie, 1972; Jackson and McKenzie, 1984, 1988). Plate tectonic models based on analysis of global seafloor spreading, fault systems, and earthquake slip vectors indicate that the Arabian plate is moving in a north-northwest direction relative to Eurasia at a rate of about 18-25 mm/year, averaged about 3 Myr. These models also indicate that the African plate is moving in a northerly direction relative to Eurasia at a rate of about 10 mm/year. Differential motion between Africa and Arabia (≈mm/yr) is thought to be taken up predominantly by left-lateral motion along the Dead Sea transform fault. This northward motion results in continental collision along the Battles-Zagros fold and thrust belt, intense earthquake activity (Figure 4) and high topography in eastern Turkey and Caucasus mountains, and western extrusion of the Anatolian plate. The leading edge of the African plate is being subducted along the Hellenic arc at a higher rate than the relative motion of the African plate itself, requiring that the arc moves southward relative to Eurasia proper. Subduction of the African plate is also thought to occur along the Cyprean arc and/or the Florence rise south of Turkey, although it is less well defined in these regions than along the Hellenic arc.

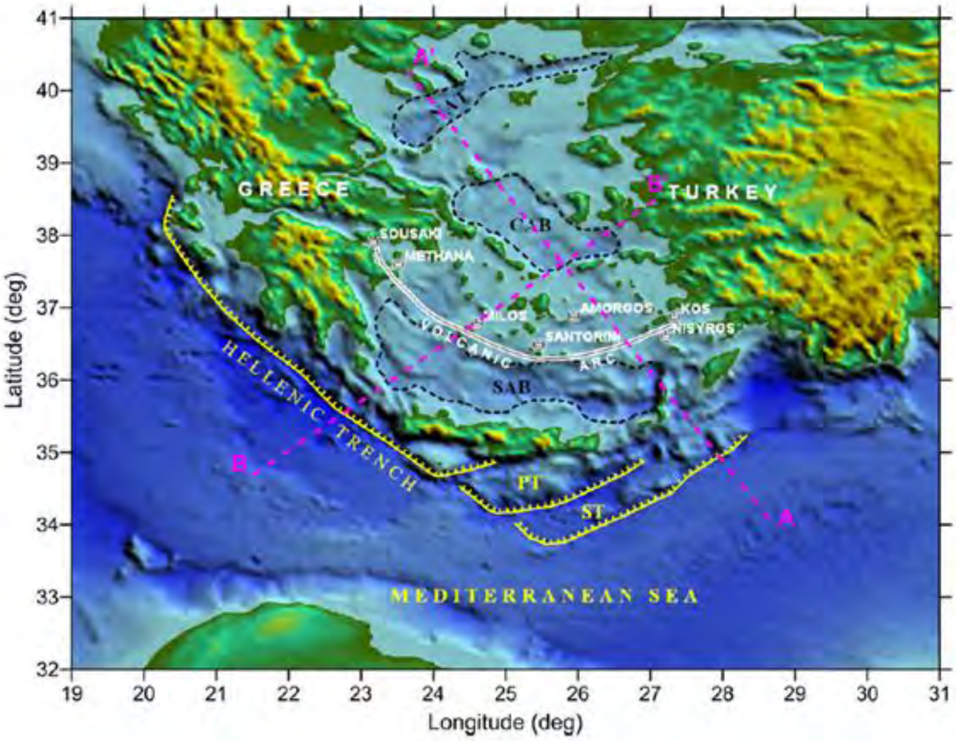

Figure 3. Simplified tectonic map of Aegean Sea and surrounding area (from Kalyoncuoglu *et al*., 2013). NAT: North Aegean Trough; CAB: Central Aegean Block; SAB: Southern Aegean Block.

Taymaz *et al*. (1991) studied the active tectonics at the north and central Aegean Sea with earthquake focal mechanism solutions. They showed that three principal effects dominate the active tectonics of the Aegean region:

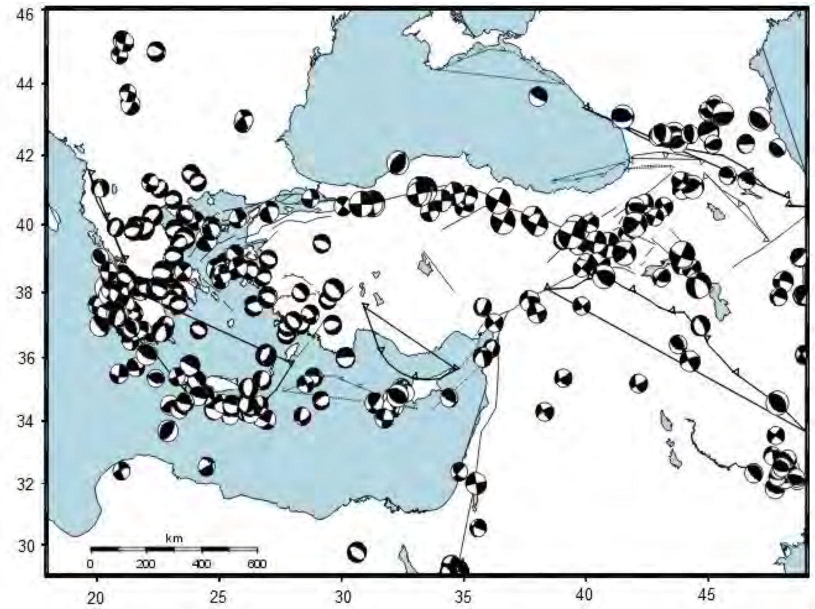

Figure 4. Seismicity of the Eastern Mediterranean and focal mechanism solutions (lower hemisphere projection) for shallow (depth of <100 km) (from McClusky *et al*., 2000).

(a) The westward motion of Turkey relative to Europe, which is accommodated by localized slip on the North Anatolian Fault in central Turkey, but by distributed right-lateral shear in NW Turkey, the Aegean Sea and Thrace;
(b) The collision between the Albania-NW Greece margin and the Apulia-Adriatic platform in the west, which leads to shortening of continental crust and a consequent resistance to the rotation of Greece and Albania that is necessary to take up the distributed right-lateral shear; and
(c) The subducted lithosphere slab beneath the southern-Aegean, which generates extension in the lithosphere above it, as it sinks into the mantle. The dramatic change in the character of the deformation, from mainly strike-slip in the east to mainly normal faulting in the west, is related to the failure of the western seaboard of Greece and Albania to rotate rapidly enough to accommodate the westward motion of Turkey. It is this that probably initiated the extension in the Aegean Sea, causing its southern margin to override the oceanic crust of the eastern Mediterranean, and leading eventually to the establishment of a sinking slab that accentuated and helps sustain the deformation. A simple model, involving broken slats attached to margins that rotate, is able to reproduce quantitatively many of the features of the instantaneous deformation field seen in the central and northern Aegean region.

McKenzie (1972), Jackson and McKenzie (1988) and Jackson (1994) developed a plate tectonic framework for understanding deformation in the eastern Mediterranean and examined the principles that control continental tectonics in the region. They suggest that continental lithosphere tends to move laterally away from zones of compression, presumably to minimize topographic relief and avoid subduction of buoyant continental material. They further suggest that the Anatolian plate moves westward from the zone of intense convergence in eastern Turkey, and they infer an Euler vector (i.e., rotation pole and rate) for Anatolian-Eurasia based on earthquake slip vectors along the North-Anatolian fault (NAF). Furthermore, they proposed the existence of the Aegean plate that moves with distinctly different velocity than the Anatolian plate and a zone of separation of the two plates by a zone of north-south extension in western Turkey. This qualitative description, which has proven remarkably robust, is clearly illustrated by the distribution of earthquake focal mechanisms shown in Figure 3, which define the "aseismic" areas of Anatolia and the southern Aegean, a zone of N-S extension in western Turkey, and the major strike-slip faults which accommodate extrusion of Turkey (McClusky *et al*., 2000).

The motion of Anatolia is bounded on the north by the right-lateral North Anatolian fault and on the south by the left-lateral East Anatolian fault. Upper bounds on fault slips rates for these faults are 24±1mm/yr and 9.1±1 mm/yr, respectively (McClusky *et al*., 2000). Relative to Eurasia, the southwestern Aegean-Peloponnesus moves towards the SSW at 30±2 mm/yr in a coherent fashion with low internal deformation (<2 mm/yr). The southeastern Aegean region deviates significantly from this coherent motion, rotating counterclockwise and moving toward the Hellenic trench (i.e., toward the SE) at 10±1 mm relative to the southwestern Aegean. Right-lateral strike-slip deformation associated with the NAF extends into the north Aegean (north Aegean trough) through the Sea of Marmara, terminating near the Gulf of Cornith. The north Aegean and trough and Gulf of Corinth form the principal northern boundary of the southwestern Aegean plate. The southern Aegean is separated from Anatolia by a zone of N-S extension in western Turkey (Figure 5).

The oceanic lithosphere of the Black Sea and southern Caspian Seas formresistant "backstop", diverting the impinging Anatolian plate to the west and "funneling" the continental lithosphere of eastern Turkey and Caucasus around the eastern side of the Black Sea. The deviation of the western section of the NAF could be explained in a similar way why it is theoretical small circle path (i.e., the fault deviates to the south to avoid the Black Sea lithosphere). This deviation may also account, in part, for the opening of the Sea of Marmara. The rapid motion of the southeastern Aegean plate requires forces other than pushing from Anatolia contribute this motion; presumably forces associated with foundering Africa plate as it subducts along the Hellenic trench. The anomalous trench ward motion in the SE Aegean represents a response to particularly rapid sinking of the down going plate below this section of the arc, possibly associated with complex bending/breaking of the subducted plate (Figure 6).

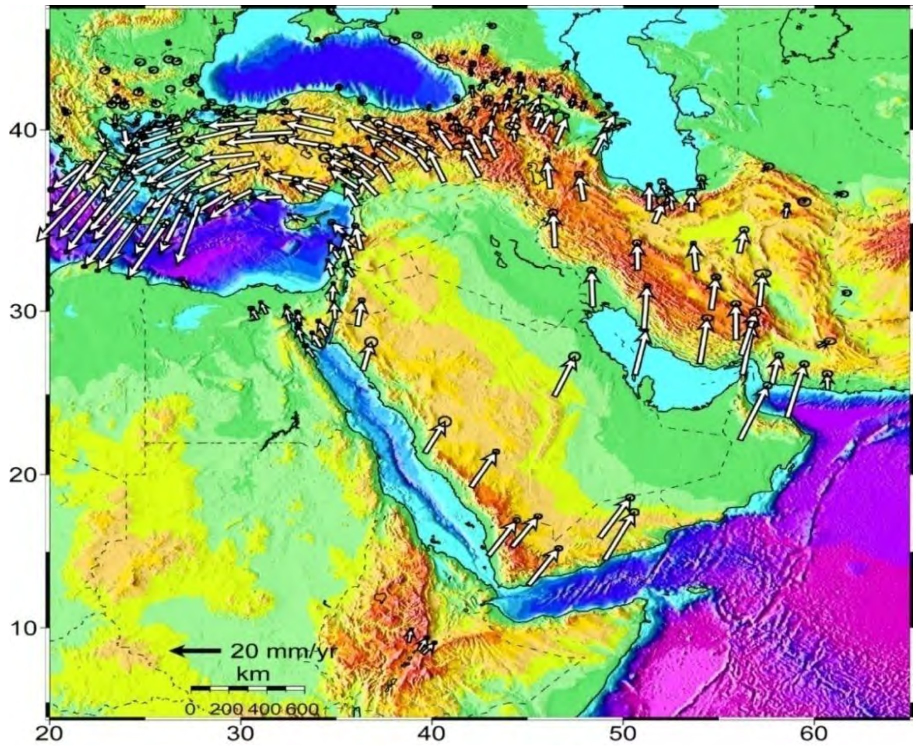

Figure 5. GPS vectors and 95% confidence ellipses in a Eurasia-fixed reference frame for the period 1988-1997 (from McClusky *et al*., 2000).

Many paleomagnetic studies have contributed to the reconstruction of the Neogene evolution of the Aegean area. Paleomagnetic studies postulated an evolution for the Aegean arc with an almost rectilinear (E-W) starting configuration between the Paleocene and the late Burdigalian. During the middle Miocene, the western (Epirus, NW Greece) and eastern Aegean arc (Beydağları mountains, SW Turkey) started to rotate clockwise, respectively anticlockwise. A second, supposedly continuous, phase of rotation was thought to have occurred only in the western Aegean arc (Ionian islands) during the last 5 Myr. Duermeijer *et al*. (2000) indicated that the western Aegean arc underwent a clockwise rotation phase, whereas the eastern arc experienced anticlockwise rotations. Furthermore, the results from the western arc indicate that the clockwise rotation phase took place between ~0.8 Ma and Recent on Zakynthos and at least<1.8 Ma on the Peloponnesus. The anticlockwise rotation phase in the south-eastern arc may be equally young (<1.8 Ma), although dating is insufficiently accurate. The current pattern of rotations to match the interpreted geodetic data, which indicate (considerable) clockwise rotations in the western arc and (small) anticlockwise rotations in the eastern Aegean.

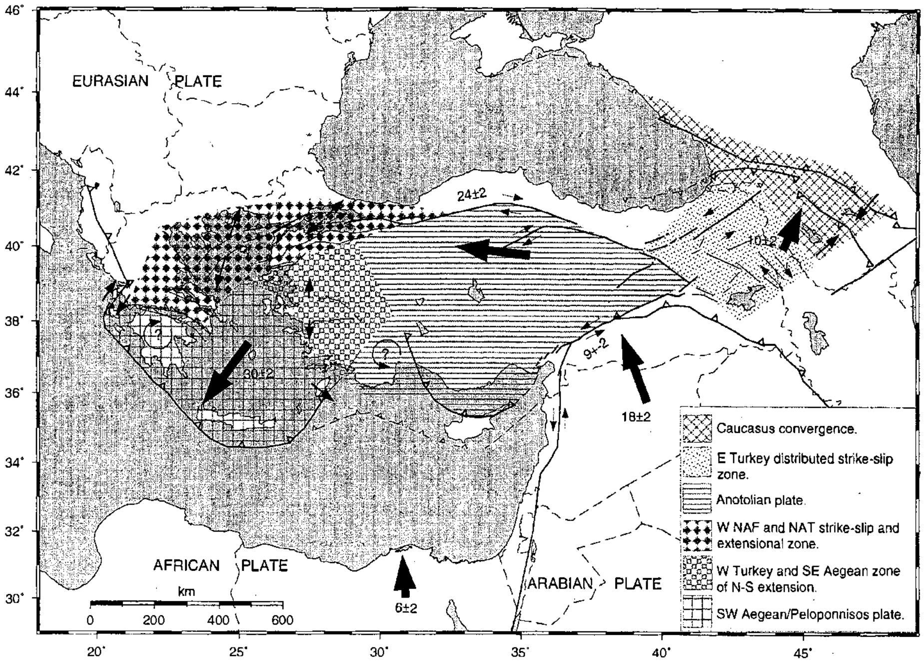

Figure 6. Schematic illustration of the principal domains in the Eastern Mediterranean. Hatching shows areas of coherent motion and zones of distributed deformation (see legend). Heavy arrows indicate generalized regional motions (McClusky *et al.*, 2000).

5. Crustal Structure, Gravity and Heat Flow in the Aegean Region

In the interpretation of gravity anomalies of the Eastern Mediterranean Region, one of the most important questions which should be considered is the inverse relations between the anomalies and the normal isostatic conditions (Figure 7). In the Eastern Mediterranean Region it is observed with interest that these conditions are completely reversed locally and generally. The Anatolian Plateau is about 1000 m above sea-level and increases up to 2000 m heights towards the east. The heights are more than 1000 m over the Taurus Mountains in the south and Pontides in the north. The Black Sea water depths reach up to 2200 m. Water depths in the Eastern Mediterranean reach to 3000 m in the Herodotus Abyssal plain (about 4000 m in the Rhodes basin, the deepest basin in the Mediterranean). The Aegean region shows intermediate conditions between western Turkey and the mainland of Greece.

The Eastern Mediterranean Basin, having 100mGal gravity values lower than other isostatically compensated oceans, it is in general overcompensated (Figure 7). Normally the Eastern Mediterranean Basin should rise under its present isostatic condition. It is known, however, that the Eastern Mediterranean Basin with its thick sediment-filled basins is actually sinking. Anatolia, having 100mGal gravity values higher than other isostatically compensated zones of the world, is in general undercompensated. Normal isostatic conditions require that Anatolia should sink. It is known, however, that Anatolia, with the exception of local grabens, is rising. While the Black Sea, having 100mGal lower gravity value than other isostatically compensated oceans, it is in general overcompensated and the Black Sea basin with very thick sedimentary cover (more than 12-14 km thick) is actually sinking.

The distribution of oceanic and continental crust in the eastern Mediterranean region is not well understood but has major implications for tectonic evolution of this region (Cowie and Kusznir, 2012). Knowledge and understanding of ocean-continent transition structure and continent-ocean boundary location at rifted continental margin is therefore a generic global problem. Gravity inversion technique, which maps Moho depth, crustal basement thickness and continental lithosphere thinning, has been developed to assist in determining this critical information (Makris, 1978). Makris (1978) prepared the moho depth map for the eastern Mediterranean (Figure 8).

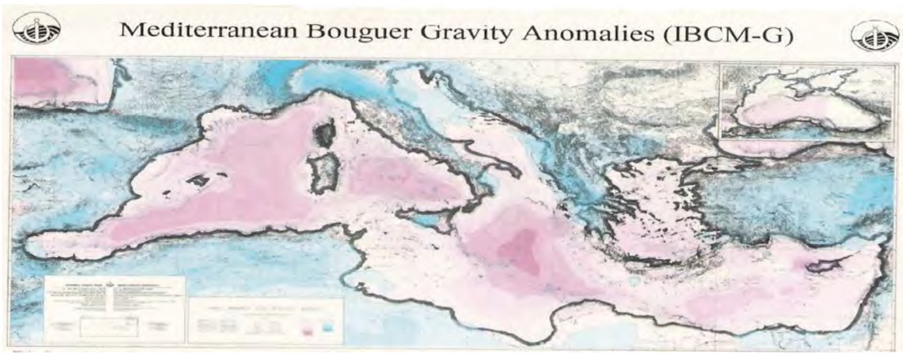

Figure 7. Bouguer gravity map of the Mediterranean prepared by the International Bathymetric Chart of Mediterranean (overlay sheets). Red colors indicate higher Bouguer gravity anomalies.

The Aegean region has shallower moho depths compared with the mainlands of Turkey and Greece. The sea areas of the Eastern Mediterranean have very shallow moho depths and the Black Sea partially so. Karagianni and Papazachos (2007) reported that in the southern Aegean Sea, as well as in the central part, the crust has a thickness of about 20-22 km. They found that the inner Aegean Sea shows a crustal thickness less than 28-30 km, whereas a significant crustal thickness of about 40-46 km is observed along the Hellenides mountain range in the western Greece.

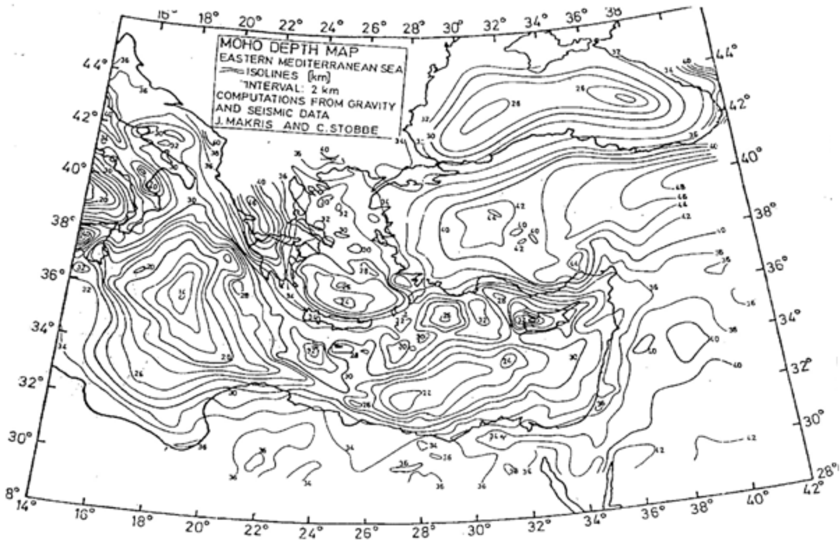

Figure 8. Moho deph map prepared from the gravity inversion (Makris, 1978).

Bonhoff *et al*. (2001) studied the crustal structure of the Hellenic subduction zone using wide aperture seismic data. They found that the crust in the Cretan region was identified to be continental with maximum thickness of 32.5 km below northern Crete, thinning towards the North and South to 15 and 17 km, but also along the strike of the main morphological structures on Crete (E-W) to 24 km (east) and 26 km (west). The velocity structure shows lateral variations within the upper crust (5.8 km/s, locally 6.5 km/s) being larger than those of the lower crust (6.4-6.9 km/s). The intracrustal discontinuity was encountered at most parts of the profiles with velocity contrasts reaching from 0.15 to 0.6 km/s. Below the continental Cretan crust, they identified a NNE-ward dipping layer that is decoupled from the overlying continental crust at approximately central Crete. This layer was interpreted as oceanic crust presently under subduction below the Aegean Sea. The southern margin of the continental Aegean lithosphere is located about 100 km south of the Cretan coast. This is indicated by a change of crustal composition of the sediments from some hundreds of meters to more than 7 km just before the northern slope of the central Mediterranean Sea.

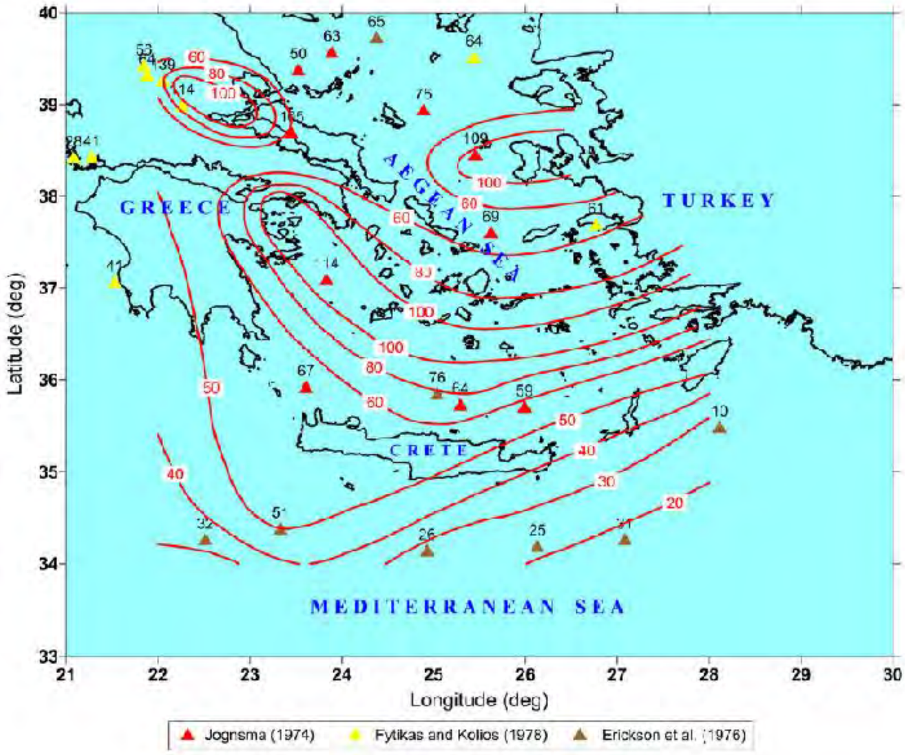

Figure 9. The heat flow contours of the Aegean region (prepared from Fytikas, 1980). Triangle symbols show the heat flow values from Jongsma (1974); Erickson *et al*. (1976) and Fytikas and Kolios (1978).

Temperature distribution within the earth's crust has important effects on the active tectonics and seismicity (Bott, 1982). The Aegean Sea is a typical volcanic activity and active seismicity. Several studies were carried out to determine the thermal state of the crust in the Aegean Sea and surroundings (Jongsma, 1974; Erickson *et al*., 1976; Fytikas, 1980; Hurtig *et al*., 1991; Ilkışık, 1995; Dolmaz *et al*., 2005). Central Aegean basin, Cycladic arc and southern Aegean basin indicate high heat flow value up to 80-120 mWm^{-2} (Jongsma, 1974; Fytikas, 1980; Hurtig *et al*., 1991) (Figure 9), where low heat flow is observed in front of the arc (Papazachos and Comninakis, 1971) showed that measured heat-flow values display a stepwise increase just to the north of Crete along a N-S profile. The Aegean region is characterized by higher than average continental heat-flow values (mostly exceeding 84 mWm^{-2}) indicating a back-arc of the region. Two hot areas can be identified in the central Aegean and in western Anatolia; whereas northwestern continental Greece and the east of Crete are characterized by low heat flow values.

The Aegean region is tectonically a complex area characterized by different crustal structure (e.g., Papazachos *et al*., 1998; Karagianni and Papazachos, 2007), effective tectonic movements (McClusky *et al*., 2000), recent volcanic activities and spatial distribution of earthquakes. The Aegean basin has been separated into several sub-basins characterized mainly by different crustal structure and tectonic regimes (Papazachos *et al*., 1998). From north to south, these sub-basins are North Aegean Trough, Central Aegean Basin, volcanic arc (Cycladic Arc, South Aegean Basin (Figure 2).

6. General Remarks

The Aegean is the sea that is surrounded between the coasts of mainland Greece, the coasts of western Turkey and Crete. The current geomorphological condition of the Aegean is the result of three main parameters: the tectonism, the volcanic activity and the eustatism (i.e. the rise and fall of the sea level). The history of the Aegean begins about 35 million years ago, when, during Oligocene, land emerged from the sea for the first time. This orogenesis, which was part of the overall Alpine orogenesis in southern Europe, was completed during the late Oligocene (approximately 25 million years ago) and the result was the creation of an extensive mountain land area covering the entire South Aegean, joining current Peloponnese and the lower part of mainland Greece with Crete and Asia Minor.

The Eastern Mediterranean and the Middle East make up the southern boundary of the Tethys Ocean for the last 200 Ma by the disintegration of the Pangaea and closure of the Tethys Ocean. It covers the structures: Hellenic and Cyprus arcs; Eastern Anatolian Fault Zone; Bitlis Suture Zone and Zagros Mountains. The Aegean region is tectonically a complex area characterized mainly by the subduction of African oceanic lithosphere beneath the Aegean continental lithosphere including extensional sub basins and mantle driven block rotations. Its southern edge is a subduction zone south of Crete, where the African Plate is being swept under the Aegean Sea Plate. To the north is the Eurasian Plate, which is a divergent boundary responsible for the formation of the Gulf of Corinth. The southern part of the Aegean has also been deformed by normal faulting but is now relatively inactive.

The leading edge of the African plate is being subducted along the Hellenic arc at a higher rate than the relative motion of the African plate itself, requiring that the arc moves southward relative to Eurasia proper. Subduction of the African plate is also thought to occur along the Cyprean arc and/or the Florence rise south of Turkey, although it is less well defined in these regions than along the Hellenic arc. The rapid motion of the southeastern Aegean plate requires forces other than pushing from Anatolia contribute this motion; presumably forces associated with foundering Africa plate as it subducts along the Hellenic trench. The anomalous trench ward motion in the

SE Aegean represents a response to particularly rapid sinking of the down going plate below this section of the arc, possibly associated with complex bending/breaking of the subducted plate.

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NUTRIENTS IN THE AEGEAN SEA

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1. Introduction

Nutrient oligotrophic or eutrophic conditions have been characterized as the principal factors affecting the marine ecosystem (Dugdale 1967; Ryther and Dunstan 1971). Certain past studies have associated oligotrophy with the absence of measurable concentrations of a nutrient (Ignatiades *et al*., 1992; Kucuksezgin *et al*., 1995), and have defined eutrophication as a qualitative parameter that indicates nutrient or organic-matter enrichment from external sources that produces high biological productivity (Ignatiades *et al.,* 1992). Thus, one important question confronts marine scientists: what are the nutrient concentration ranges or levels characterising oligotrophic and eutrophic water types? The importance of this question lies in its association with eutrophication assessment and water quality standards (Friligos, 1987; Ignatiades *et al*., 1992).

The nutrient inputs (particularly nitrates and phosphates) as a consequence of major anthropogenic sources such as industrial, domestic and agricultural activities to the coastal areas have increased greatly during the past centuries. These anthropogenic influents as well as natural inputs (changes in precipitation inputs, erosion, weathering of crustal materials) would be expected to have an effect on natural biogeochemical processes (Belias *et al*., 2007). Nutrients are essential chemical components of life in the marine environment phosphorus and nitrogen are incorporated into living tissues while silicon is necessary for the formation of the skeletons of diatoms and radiolaria (Basturk *et al*., 1986). Nitrogen and phosphorus are described as biolimiting elements because of the effects on biological growth. In the sea, most of the nutrients are present in sufficient concentration, and the lack of some of them limits the growth of phytoplankton (Pojed and Kveder, 1977).

The nutrient enrichment, or eutrophication, can lead to highly undesirable conditions in ecosystem structure and function. The recent researches indicated that the eutrophication had influences on transportation and transformation of contaminants in aquatic environment and causes outstanding environmental problems (Zhang *et al*., 1999; Aydin Onen *et al*., 2012). Nowadays pollution from the nutrients (N and P) and organic matter represents the largest source of degradation in coastal waters. The concentrations of biologically available nitrogen and phosphorus are well known to play a key role in determining the ecological status of aquatic systems (Jarvie *et al*., 1998). And in coastal ecosystem the sources of nutrients and organic matter can be classified into two groups, that is, the point and non point sources. Point sources, such as domestic and industrial wastewater, flow out at discrete, identifiable locations and their impacts can be measured directly. However, the largest nutrient contribution for coastal marine environments is from non-point sources that are rather diffused and highly variable from year to year depending on climate and rainfall (Borum, 1996). The most important non point loads include the wet and dry deposition from the atmosphere, the erosion of land, the weathering of minerals and anthropogenic sources. The latter are directly related to human activities. Human disturbance has resulted from activities that mobilize the nutrients through land clearing, production and applications of fertilizer, discharge of human waste, animal production, accumulation of dust and litter, erosion of soil materials from agricultural farming and animal feedlots (Novotny and Chesters, 1981). As a result of these activities, the fluxes of N and P have been accelerated at coastal waters.

2. General Aspects of Pollution along the Aegean Sea

The Aegean Sea is one of the eastern Mediterranean sub basins located between the Greek and Turkish coast and the island of Crete and Rhodes. It's maximum depth 2500 m north of Crete. In the southeast, the Aegean Sea joins the Levantine Sea through three passages between the island of Crete and Karpathos (Cassos strait), the island of Karpathos and Rhodes (Karpathos strait) and Rhodes and Turkey. In the southwest, it joins the Ionian Cretan Seas through three wide passages between the island of Crete and Peloponnese (Laskaratos, 1983). There is considerable exchange of waters through each of these straits, thus linking strongly the water circulation in the Aegean Sea to the hydrodynamics of the eastern Mediterranean (Unluata, 1986). The Aegean Sea is one of the most oligotrophic parts of the Mediterranean Sea. Although nitrogen and phosphorus levels are low in general, concentrations of nutrients are higher than the Mediterranean Sea in some regions.

There is no industry in the area surrounding the northern part of the eastern Aegean coast except Çandarlı Bay. Çandarlı Bay has been strongly affected by growing population and industrialization. There are only maritime and tourism activities along the southern part of the eastern Aegean coast.

Nutrient oligotrophic or eutrophic conditions have been characterized as the principal factors affecting the local marine ecosystem (Ryther and Dunstan, 1971).

Results of several past studies have associated oligotrophy with the absence of measurable concentrations of a nutrient (Ignatiades *et al*., 1992; Kucuksezgin *et al*., 1995), and eutrophication has been defined as a qualitative parameter in which there is nutrient or organic matter enrichment from external sources that results in high biological productivity (Ignatiades *et al*., 1992).

There are many rivers, which transport nitrogen and phosphorus into the northern Aegean. The order of magnitude of the fresh water inputs is 1000 m^3 s^{-1} in total along the Aegean coastline and this value is higher than in other Mediterranean regions (IMST-096, 1997).

Izmir Bay is one of the great natural bays of the Mediterranean (western Turkey) and compares well with similar coastal areas in the world. The main urban conurbation around the Bay is the Izmir Metropolitan Municipality, covering 88 000 hectares. Izmir is an important industrial, commercial and cultural focal point. The Bay (Figure 1) has been divided into three sections (Outer, Middle and Inner) according to the physical characteristics of the different water masses. It has a total surface area of over 500 km^2, water capacity of 11.5 billion m^3, a total length of 64 km and opens in the Aegean Sea.

The Outer Bay extends from Kokola point to the mouth of the bay (Figure 1). The water volume of the Outer Bay is 1×10^{10} m^3, and it has an average water depth of about 49 m. The surface area of the Outer Bay is approximately 417 km^2. Pollution in the Outer Bay is not significant, and this part of the bay is relatively clean according to most pollution indicators. The Middle Bay extends from the Yenikale lighthouse to Kokola point. The water volume of the Middle Bay is 9×10^8 m^3 and has an average water depth of about16 m. The surface area of the Middle Bay is approximately 57 km^2.

A 13-m-deep sill, the Yenikale Strait, separates the Middle Bay from the Inner Bay. The Inner Bay is heavily polluted by nutrients and other organic materials, but metal concentrations were not so high as to label the waters as being polluted by heavy metals. Industrial fluxes of Cr, Cd and Hg to the bay were 6700, 20 and 70 kg $year^{-1}$, respectively. Data are not available on fluxes of heavy metals that result from domestic discharges. Amounts equal to 105,000 m^3 day^{-1} of industrial and 308,000 m^3 day^{-1} of domestic wastewater were discharged to the bay without significant treatment (UNEP,1993) until 2000. In early 2000, a wastewater treatment plant (WTP) began operation to treat domestic and industrial wastes. Eutrophication of the Inner Bay is a serious problem throughout the year and red tide events are becoming more frequent (UNEP, 1993; IMST-070/A, 1991; Kucuksezgin, 2011).

The sources of pollution are streams and hundreds of small domestic discharge outlets, which flow to the Bay. The main industries in the region include food processing, beverage manufacturing and bottling, tanneries, vegetable oil and soap production, paint production, chemical industries, paper and pulp factories, textile industries, metal processing, a petroleum refinery, a petrochemical complex, timber products and processing.

There have been a number of studies focused on the levels of nutrients and physicochemical variables of the water column in Izmir Bay (Kocak and Kucuksezgin, 2000; Kontas *et al*., 2004; Kucuksezgin *et al*., 2005; Kucuksezgin *et al*., 2006; Kukrer and Aydın, 2006; Basaran *et al*., 2010; Sunlu *et al*., 2012a; Sunlu *et al*., 2012b. Very few published data are available on nutrient concentrations in the Aegean. Distribution of nutrients was investigated by Friligos (1983), Ignatiades *et al*. (2002); Kucuksezgin *et al*. (1995) in the Aegean Sea. A national monitoring programme was performed in the framework of MEDPOL Phase IV in the eastern Aegean Sea (IMST-165, 2007, IMST-165, 2008, IMST-165, 2009). These projects include the monitoring of pollution trends at coastal and hot spots and the monitoring of contaminant levels in biota and sediments to follow long-term changes of the chemical pollutants.

3. Nutrients

3.1 Aegean Sea

Much attention has been focused on the ecosystems of the oligotrophic seas which constitute the majority of the world's ocean surface. The Aegean Sea is one of the most oligotrophic parts of the Mediterranean Sea and although it is of limited productivity, wastewater and river estuaries constitute nourishment areas for aggravated growth because of local nutrient additions from pollution.

Chemical, physical, biological and geological characteristics of the Aegean Sea were investigated in the framework of a National Marine Measurement and Monitoring Programme supported by TUBITAK (The Scientific and Technological Research Council of Turkey). Nutrient, chlorophyll-a, heavy metal total suspended solid and PAH data were collected during cruises of *R/V* K. Piri Reis (Dokuz Eylul University Institute of Marine Sciences and Technology) between 1986-1990 at point sources (10), coastal (10) and open sea (32) sampling stations (DEBCAG-8G, 1986, DEBCAG-8G, 1987, DEBCAG-61G, 1988, DEBCAG-44G, 1989, DEBCAG-88G, 1990) (Figure 1). The highest level of nutrients and chlorophyll-a were measured in Izmir and Aliağa Bays.

Kucuksezgin *et al*., (1995) investigated the distributions of nutrients and chlorophyll-a in the Aegean Sea in the framework of a National Marine Measurement and Monitoring Programme for the Aegean Sea. The data were collected as part of six cruises from 41 sampling points between 1992-1994 (Figure 1). Concentrations of nutrients were lower than those previously reported for the Black Sea; generally lowest at the surface, they increased with depth. The highest nutrient values were found in the northern part of the Aegean Sea and may have resulted from originating from the Black Sea. Nutrient values increase with increasing depth. Nitrate, ammonium, phosphate and silicate ranged between 0.10-2.90, 0.10-0.95, 0.01-0.16, 0.30-4.70 μM, respectively. Elemental ratios of N/P, Si/P were calculated as 13.6-36.8 and 14.0-48.0, respectively. Concentrations of chlorophyll a ranged from 0.03-0.70 μg/l in the Aegean Sea.

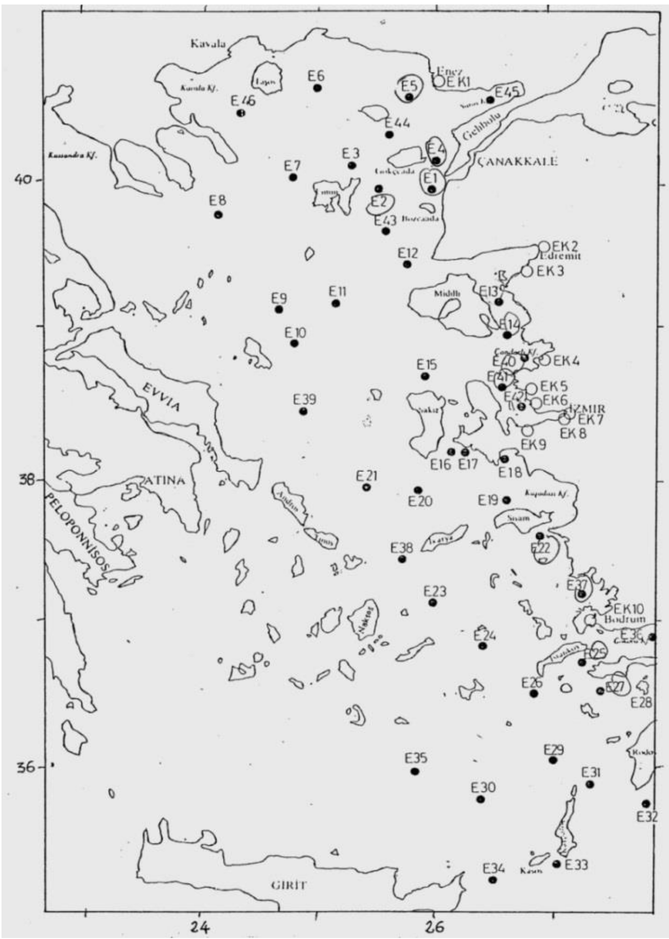

Figure 1. Location of sampling stations in the Aegean Sea (from DEBCAG-8G, 1986; DEBCAG-8G, 1987; DEBCAG-61G, 1988, DEBCAG-44G, 1989; DEBCAG-88G, 1990; Kucuksezgin *et al*., 1995).

Kocak and Kucuksezgin (2000) investigated relationship between physicochemical parameters in water column and sessile fouling organisms during 1993-1994 in different marinas from the eastern Aegean Sea. Pollution resistant macrobenthic species were discussed.

Ignatiades *et al*. (2002) performed a multidisciplinary project and data were collected from six stations in the north and five stations in the south part of the Aegean Sea during three cruises between 1997-1998. Mean values of phosphate, ammonium, nitrate+nitrite, silicate were measured as 0.019-0.032, 0.07-0.16, 0.29-0.62, 1.21-2.40 µM in the northern Aegean and 0.013-0.049, 0.21-0.40, 0.40-0.88, 1.18-1.63 µM in the southern part of Aegean Sea, respectively. Chl-a and primary production ranged between 0.26-0.38 μg/l, 0.26-1.84 mg C m^{-3} h^{-1} in the north Aegean and 0.12-0.30 μg/l, 0.17-0.51 mg C m^{-3} h^{-1} in the south Aegean, respectively. Maximum values were found in spring season during sampling periods.

The main results of multidisciplinary and integrated studies were summarized by Lykousis *et al*. (2002). According to this study, the nutrient, POC, chlorophyll-a, phytoplankton and mesozooplankton abundance, primary production and bacteria production levels, although higher in the northern part of Aegean than in the southern part of Aegean, reflect clearly the highly oligotrophic character of the entire Aegean Sea.

Pazı (2008) performed a study in the Northeast Aegean Sea and explained a description of the water masses and chemical properties in the Saros Gulf. The nutrient levels varied between NO_3+NO_2:0.19–0.37, PO_4:0.01–0.02 and silicate:0.7–1.1 μM for the surface layer during sampling periods. Dissolved nutrient concentrations in the North Aegean Deep Water were: 1.7–3.7 μM for NO_3+NO_2, 0.08–0.17 μM for PO4 and 2.7–4.2 μM for silicate. During winter, relatively high nutrient levels are observed in the surface layers of the NE Aegean Sea, whilst phosphate and nitrates decrease in summer.

Aydin Onen *et al.* (2012) assessed the state of the five stations' quality on the basis of determination of temporal and spatial variability of nutrients with physicochemical variables. The samples were collected seasonally from different areas such as harbor and important touristic marinas along the eastern Aegean during June 2008–2009. As a result, the nutrients ranged between NH_4: 0.10–25.6, NO_3: 0.19–7.0, o.PO_4: 0.17–6.8, TPO_4: 0.32–9.6 and Si: 0.30–13.8 μM. The relatively high nutrient increase in the sampling stations coupled with surface runoff events during rainy period and pollution arising from both point and non-point sources.

Yucel-Gier *et al*. (2013) performed a spatial analysis of marine fish farming using several GIS data layers to assess Allocated Aquaculture Zone (AZA) and to monitor operations in Güllük Bay (Eastern Aegean). This study used water quality index (TRIX) data for evaluation in conjunction with GIS. The study showed how different terrestrial and marine activities interact with each other, and that certain areas are subject to layers of multiple usages and water quality index (TRIX) data was evaluated by using a GIS.

The dynamics of dissolved organic matter in the Marmara Sea–Dardanelles Straits–North Aegean Sea were investigated using measurements of dissolved organic carbon and nitrogen (DOC, DON), bacterial production (BP) and respiration rates by Zeri *et al*. (2014). In the surface brackish waters, chemical parameters showed an increase from the Aegean to the Marmara, followed by an increase in BP rates. In the subsurface waters, DIN also showed an increase in the Marmara basin followed by an increase in BP rates.

3.2 Izmir Bay

Eutrophication problems have occurred in many coastal areas. Such problems derive from conditions characterized as follows: areas that are enclosed or semi-enclosed and have poor water exchange are affected by urban and industrial wastewaters and/or receive nutrient inputs from rivers and urban activities. There is an apparent eutrophication problem in such bays due in large measure to inputs of nutrients and organic matter into the shallow zone that then has limited exchange with the open sea. Much of the polluting nutrients and organic materials derive from domestic sewage from high population density, coastal agglomeration, and tourism.

The water quality in the Izmir Bay has been significantly affected by past and continuing coastal and industrial development. Nutrient concentrations in the bay have been dramatically changed by the conversion of natural creeks and freshwater inputs to WTP from the large and rapidly expanding Izmir metropolitan area.

Buyukisik (1986), Buyukisik and Erbil (1987), Buyukisik *et al*. (1997) investigated nutrient dynamics in the inner part of the Izmir Bay. Size-fractionated phytoplankton and nutrient dynamics in the inner part of Izmir Bay was also evaluated by Kukrer and Buyukisik (2013).

Kucuksezgin *et al*. (2005) investigated seasonally temporal variations and regional distribution of particulate organic matter, dissolved nutrients and chlorophyll-a in the bay. The data were collected during four cruises between March 2000 and January 2001 at selected sampling points within the framework of the Izmir Bay Marine Research Project. The particulate concentrations varied between 3.2 and 23 for POC, 0.32 and 2.1 for PON, 0.02 and 0.21 μM for PP in the outer and 12 and 197 for POC, 1.7 and 30 for PON, 0.11 and 1.9 μM for PP in the middle–inner bays. Atomic ratios of particulate matter from the regression equations were similar to off-shore Mediterranean Sea and lower than near-shore Black Sea in the outer bay. POC:PON:PP ratios were mostly greater than the Black Sea in the middle and inner bays. Mean DIN:DIP ratios in the water column were 14 and 3.5 in the outer and middle–inner bays, respectively, which are lower than the Redfield ratio.

The impact of a sea bass farm on water quality and benthic community structure was investigated at a fish farm site in Engeceli Bay (western part of Izmir Bay) between April 2001 and February 2002 by Yucel-Gier *et al*. (2007). The characteristics of the water column in the fish farm were evaluated in terms of physical and chemical parameters. Concentrations of nitrate, phosphate and ammonium ions in all sampling stations within the Bay were compared with the water quality parameters measured at the outer part of Izmir Bay.

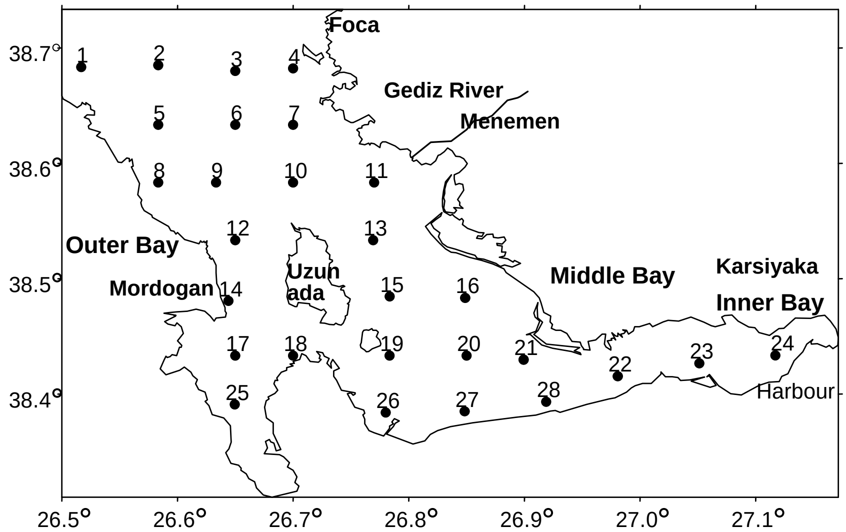

Figure 2. Sampling stations in Izmir Bay

Kucuksezgin (2011) evaluated the nutrient loadings input to Izmir Bay during the period 1996–2008 in the review (Figure 2); such inputs to the bay have come from the Gediz River, from the atmosphere, and from the natural creeks that empty into it. The water quality of Izmir Bay has perhaps been most significantly affected by the Gediz River, which drains surrounding agricultural and urban areas. The average nutrient concentrations from all depths in the Outer Bay ranged between 0.01 and 0.22, 0.10 and 1.8, 0.10 and 0.98, 0.30 and 5.9 μM for orthophosphate-phosphorus (*o*-PO_4-P), (nitrate+nitrite)-nitrogen (TNO*x*-N), ammonium (NH_4-N), and reactive silicate ($Si(OH)_4$), respectively. In the Middle–Inner Bays, the ranges of nutrient concentrations were 0.01–10, 0.12–27, 0.10–50, 0.43–39 μM for *o*-PO4-P, TNO*x*-N, NH_4-N, and [$Si(OH)_4$], respectively.

The results indicate that nitrogen is the limiting element in Izmir Bay. The stations in the Outer Bay have an average N:P ratio of 9.8, while the average ratio at stations in the Middle and Inner Bays is 4.5 owing to the different characteristics of the seawater. Positive correlations were found between o.PO_4-P and TNOx-N in all parts of the bay.

Yucel-Gier *et al.* (2011) examined the current water quality status of Izmir Bay, using the trophic index (TRIX) as a tool for the regulation of Turkish marine finfish aquaculture. Use of the composite trophic status index (TRIX) produced mean TRIX values of 3.6 for the aquaculture area (AA) and 2.5 for areas of the outer bay where no aquaculture takes place; this indicates ‘no risk of eutrophication’ as defined by Turkish law. The study then applied the UNTRIX indices adjusted to local conditions, revealing that both the inner bay and the aquaculture area (AA) can be classified as of ‘poor’ status whereas the outer bay can be defined as ‘good’.

Sunlu *et al*. (2012a) and (2012b) studied nutrient and chlorophyll a trends after Wastewater Treatment Plant in Izmir Bay and evaluated the relationships between N:Si:P molar ratio and coastal marine phytoplankton in İzmir Bay.

3.3 River inputs

Several major rivers discharge into the Aegean Sea, such as Meric (Maritza River), Nestos, Strimon, Axios and Pinios discharge in the north and Bakırcay, Gediz, Büyük and Küçük Menderes in the east. These rivers drain southeastern Europe and western Turkey with a combined annual water discharge ranging between 400 and 2400 m^3 /s through the Dardanelles. Most of this outflow occurs during the summer (peak in August), closely correlating with the maximum discharge of large rivers draining into the Black Sea, such as Dnieper, Dniester, Don, Danube and Bug.

The Büyük Menderes River is the biggest river of the Aegean region of Turkey. The total length is approximately 530 km. Forty percent of this length is located in the region of Denizli city. The surface area of the river is $200km^2$. The river’s elevation varies between 70m and 500m above sea level. Cotton, wheat and corn are the traditional crops grown in these lands with traditional irrigation methods (Dugel and Kazanc, 2004).

The Gediz River, which flows to the outer part of the Izmir Bay (western Turkey), is the second biggest river along the eastern Aegean coast. The Gediz River drains a basin that is 15,616 km^2 in area and has an average annual discharge rate of 40–70 $m^3\ s^{-1}$ (EIE 1984). The Gediz River is known to be under contamination menace by wastes derived from industrial sources, sewage and agricultural activities. The seaward fringe of Gediz Delta is an important nature reserve and has recently been designated as a RAMSAR (The convention wetlands of international importance especially as waterfowl habitat) site to protect rare bird species (MEF, 1995; MEF, 2000). Originally, the area received excess water from the Gediz River for much of the year, but since 1990, with restrictions on irrigation releases, the reserve suffers from water shortages. The Gediz Delta comprises an extensive coastal wetland that has bays, salt and freshwater marshes, large saltpans, and four lagoons that have formed at the mouth of the Gediz River. This river, of course, transports wastes; to prevent soil particles from settling out before reaching the sea and to provide sufficient dilution to avoid in-stream environmental harm, the flow rate of the river must have sufficient velocity to keep organic compounds or metals that are adsorbed to particulates, in suspension.

The Bakırçay is a considerably small river, drains into Çandarlı Bay and the water depth exceeds 140 m in the central of the basin. The Çandarlı Bay is polluted by tanker traffic, refineries and tanker-filling installations as well as organic loads from the Bakırçay River.

Kaymakçı Başaran (2011) investigated water quality parameters in the estuary of Küçük Menderes River from the eastern Aegean Sea.

The state of these rivers were investigated in the framework of the "The National Monitoring Programme for the Control of Pollution" in conjunction with the MED POL-PHASE IV International Project in order to assess the effects of rivers and effluents reaching to the Aegean and Mediterranean Sea (IMST-165, 2008; IMST-165, 2009). Nutrient concentrations were evaluated and the results from the rivers were compared by Kucuksezgin *et al*. (2008) and Kucuksezgin *et al*. (2009).

The higher concentrations of total phosphorus, ammonium, o.PO4 were recorded in the Küçük Menderes River. The nitrate nitrogen and silicate in the Bakırçay River; nitrite nitrogen in the Gediz River were found to be higher than in the other rivers. The flow rate of Küçük Menderes River is low and there is no any dam built on this river, so all the waste waters reaching the river are transported to sea; this effect becomes more evident during the rainy seasons. Coastal waters nourished by river waters are rich with nitrate and silicate; therefore, they have high biodiversity and biomass. The minimum dissolved oxygen concentrations were also measured in the Küçük Menderes River during all sampling periods. These results show very clearly that there are large loads of domestic waste water inputs to the Küçük Menderes River. Thus, bacterial degradation of organic matter resulted in drastic oxygen deficiencies in polluted rivers with high ammonia concentrations.

The flow rates of rivers (10^8-10^9 m^3/year) are higher than effluents (10^6-10^7 m^3/year) and because of that reason; the rivers transfer more pollutants to the Aegean coasts. The highest levels of o.PO_4, nitrate, nitrite loads flow to the Aegean Sea by the Gediz River; ammonium by the Küçük Menderes River; total phosphate and silicate by the Büyük Menderes River. The lowest loads of total and reactive phosphate reached to the Aegean coast by Bakırçay River to the Aegean Sea whereas nitrate, nitrite and silicate input by Küçük Menderes River water to the Aegean Sea. Minimum loads of ammonium flow by Büyük Menderes River.

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BIODIVERSITY OF MARINE ALGAL FLORA OF THE AEGEAN COASTS OF TURKEY

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1. Introduction

Coll *et al.* (2010) and Cormaci *et al.* (2012) reported 1117 taxa at specific and infraspecific level of the marine benthic macroalgae (270 Phaeophyceae, 657 Rhodophyta, and 190 Chlorophyta) in the Mediterranean Sea (Table 1, Figure1), 109 of which alien taxa (10%), 251 of which endemic taxa (22%), and 753 of which other taxa (68%) (Figure 2). Furnari *et al.* (2010) reported 212 brown algal, 534 red algal and 150 green algal taxa from Italy, and the numbers of marine algae are greater in Italy than other Mediterranean countries (Figure 3).

Table 1. Biodiversity of the Mediterranean macrobenthic algal flora and its percentage (%).

Macroalgal groups	No.taxa	No. alien taxa	No. endemic taxa	Other taxa	% Alien taxa	% Endemic taxa	% Other taxa
Phaeophyceae	270	22	81	166	8,14	30,0	61,48
Rhodophyta	657	71	150	434	10,80	22,83	66,05
Chlorophyta	190	16	20	153	8,42	10,52	80,52
Total taxa	1117	109	251	753	9,75	22,47	67,41

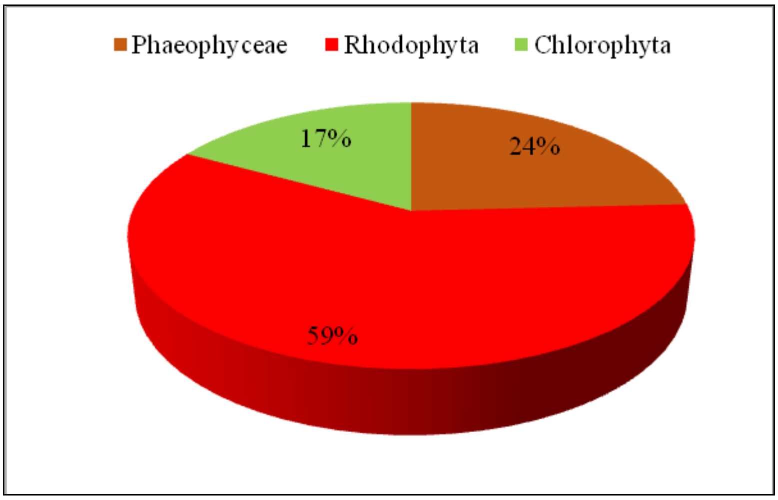

Figure 1. Percentage (%) of the Mediterranean macrobenthic algal flora.

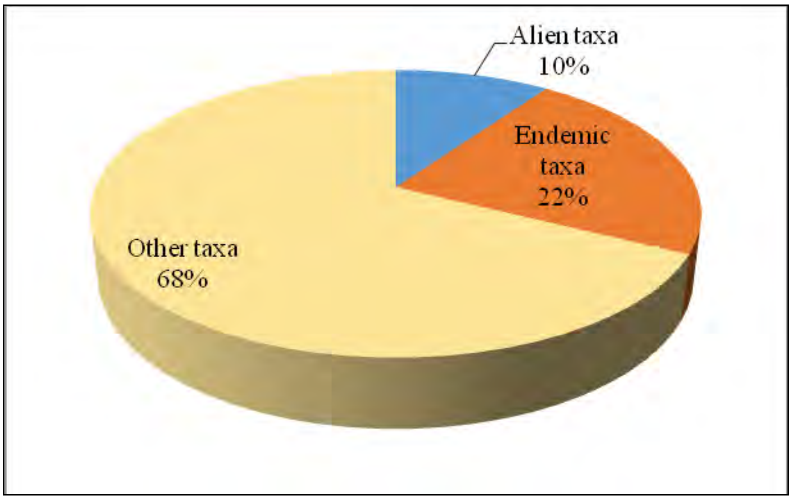

Figure 2. Percentage (%) of the alien and endemic macrobenthic algal taxa in the Mediterranean Sea.

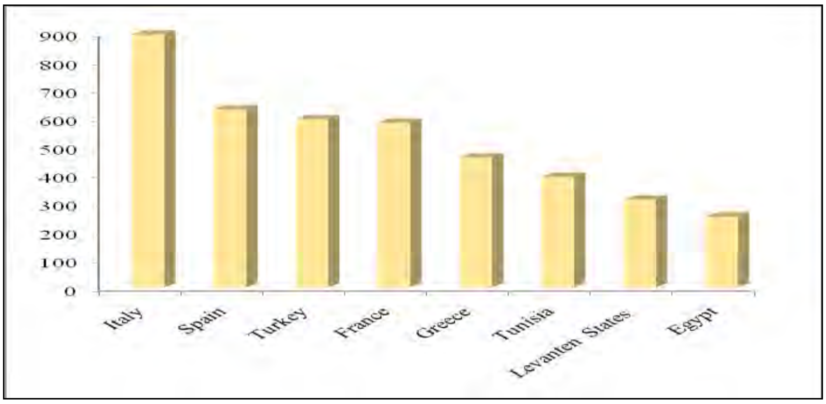

Figure 3. The number of macroalgal taxa in the Mediterranean Countries.

Turkey is washed by four seas (Mediterranean Sea, Aegean Sea, Sea of Marmara, and Black Sea) and its coasts have different structure (physicochemical parameters of water, coastline shape, etc.). In total, 600 marine benthic macroalgae have been reported from Turkey, including 150 Phaeophyceae (brown algae), 330 Rhodophyta (red algae) and 120 Chlorophyta (green algae), and 32 of which are alien taxa(5,33%) (Taşkın *et al.*, 2008, 2011; Taşkın and Öztürk, 2013) (Table 2). Turkey has 53,71% of the Mediterranean macrobenthic algal flora (Table 3).

Table 2. Biodiversity of Turkish macrobenthic algal flora and its percentage (%).

Macroalgal groups	No. taxa	No. alien taxa	% taxa	% alien taxa
Phaeophyceae	150	14	25	9,33
Rhodophyta	330	12	55	3,63
Chlorophyta	120	6	20	5
Total taxa	600	32	100	5,33

Table 3. Biodiversity of Turkish and the Mediterranean macrobenthic algal flora and its percentage (%).

Macroalgal groups	No. taxa of Mediterranean	No. taxa of Turkey	% taxa of Turkey/Mediterranean
Phaeophyceae	270	150	55,55
Rhodophyta	657	330	50,22
Chlorophyta	190	120	63,15
Total taxa	1117	600	53,71

2. History of marine algal studies from the Aegean coast of Turkey

The first paper in which macroalgae from the Aegean coasts of Turkey were reported is that by Forsskål (1775) who recorded from the islands of Gökçeada and Bozcada only three species: *Ulva intestinalis* L., *Fucus pavonicus* L. and *Conferva viridis* Forssk., and he reported 16 species of seaweeds totally from Turkey (Taşkın and Pedersen, 2008). Later, plants from Mytilene and Gulf of Izmir were quoted by Kuckuck (1958). The marine algae of the Aegean coasts of Turkey have been investigated by Karamanoğlu (1964), Zeybek (1966, 1973), Güner (1970, 1974), Güven and Öztığ (1971), Cirik (1978), Aysel (1983), Aysel and Güner (1977), Aysel *et al.* (1986, 1997),Güner *et al.* (1983-1984), Sukatar (1983), Öztürk (1983, 1988, 1993, 1996a, 1996b), Öztürk and Güner (1986), Dural (1988, 1989), Dural *et al.* (1990, 1997), Kurt *et al.* (2000, 2001), Taşkın (2006, 2008, 2012, 2013a,b), Taşkın and Öztürk (2005,2007, 2008), Taşkın and Sukatar (2013), Taşkın *et al.* (2007a,b, 2010a,b) and Aktan (2009). Numbers of marine algal taxa in the some areas from the Aegean Islands and Aegean coats of Turkey are given in Table 4, and the areas are showing in Figure 4.

Table 4. Numbers of marine algal taxa from the some areas in the Aegean coats of Turkey**.**

Area/Station	Reference	Macroalgal groups			Total taxa
		Phaeophyceae	Rhodophyta	Chlorophyta	
Gulf of Saros	Okudan (2006)	64	124	68	256
Gökçeada	Aysel *et al.* (2001)	82	182	64	328
Bozcaada	Aysel *et al.* (2005)	88	224	75	387
Edremit	Taşkın *et al.* (2009)	64	92	32	188
Ayvalık	Taşkın and Öztürk (2005)	51	66	30	147
Çandarlı	Taşkın *et al.* 2007a)	47	51	26	124
Foça Islands (İzmir)	Aysel *et al.* (2001)	76	156	61	293
Gulf of İzmir	Dural and Aysel (2007)	114	262	112	488
Karaburun Islands (İzmir)	Okudan *et al.* (2001)	63	106	46	215
Kuşadası	Taşkın (2015, unpublished)	35	85	32	152
Didim	Taşkın (2015, unpublished)	42	90	35	167
Bodrum	Taşkın (2015, unpublished)	55	94	41	190

Figure 4. Documented marine algal studies in the some areas from the Aegean Islands and Aegean coats of Turkey (1-Gulf of Saros; 2-Gökçeada; 3-Bozcaada; 4-Edremit; 5-Ayvalık; 6-Çandarlı; 7-Foça Islands; 8-Gulf of İzmir; 9-Karaburun Islands; 10-Kuşadası; 11-Didim; 12-Bodrum).

Several studies have been made on the marine algae from the Aegean coasts of Greece by Nizamuddin and Lehnberg (1970), Tsekos and Haritonidis (1974), Haritonidis and Tsekos (1974), Athanasiadis (1985), Sartoni and Biasi (1999), and Tsiamis *et al.* (2008, 2010, 2013, 2014).

3. Current status of marine algae from the Aegean coasts of Turkey

The Turkish marine algae have a greater representation both means species diversity and abundance in the Aegean coasts of Turkey (430 taxa at specific and infraspecific level) and Sea of Marmara (400 taxa) than the Mediterranean coasts (382 taxa), and Black Sea coasts (244 taxa), respectively (Taşkın *et al.,* 2008)(Table 5). The total number of taxa currently present in the Aegean Sea is: Phaeophyceae (brown algae) 111 taxa, the phylum Rhodophyta (red algae) 238 taxa, and the phylum Chlorophyta (green algae) benthic representatives81 taxa.

Photophilic and sciophilous macroalgal vegetation in the midlittoral zone from the Aegean coasts of Turkey representatives by the brown algae (Phaeophyceae) *Cystoseira barbata, C. corniculata*, *C. crinita*, *C. foeniculacea, Ectocarpus* spp., the red algae (Rhodophyta) *Jania rubens, Laurencia obtusa, Ganonema farinosum, Ceramium* spp., *Polysiphonia* spp., *Phymatolithon lenormandii*, the green algae (Chlorophyta) *Ulva* spp., and *Cladophora* spp. (Figure 5).

Photophilic and sciophilous macroalgal vegetation in the infralittoral zone the representatives by the brown algae (Phaeophyceae) *Cystoseira compressa, Cystoseira spinosa, Dictyota* spp., *Halopteris scoparia*, *Padina pavonica*, the red algae (Rhodophyta) *Peyssonnelia* spp., *Gracilaria bursa-pastoris, Nitophyllum punctatum*, *Botryocladia* spp., *Grateloupia filicina*, the green algae (Chlorophyta) *Caulerpa cylindracea*, *Codium bursa*, *Halimeda tuna, Flabellia petiolata,* and *Valonia* spp. (Figures 6-7).The coralligenous habitats are common in the Mediterranean Sea, and they have most important productive and biodiversity, and sciaphilous coralline algae are abundant in these communities.The coralligenous red algae *Lithophyllum stictaeforme*, *Mesophyllum alternans*, *M. expansum*, and *Peyssonnelia polymorpha* are known common in the Aegean coast of Turkey (Figures 8-9).

Table 5. Macrobenthic algal flora of Turkey (Taşkın *et al*., 2008, Taşkın and Öztürk, 2013).

Macroalgal groups	Mediterranean coasts of Turkey	Aegean coasts of Turkey	Sea of Marmara	Black Sea coasts of Turkey	Total
Phaeophyceae	80	111	105	58	150
Rhodophyta	220	238	225	136	330
Chlorophyta	82	81	70	50	120
Total taxa	382	430	400	246	600

Figure 5. Macroalgal vegetation in the midlittoral zone from the Aegean coasts of Turkey (2 m, Ildır Bay, Turkey). (a: *Janiarubens*, b: *Laurenciaobtusa*). (Photo: E.Taşkın).

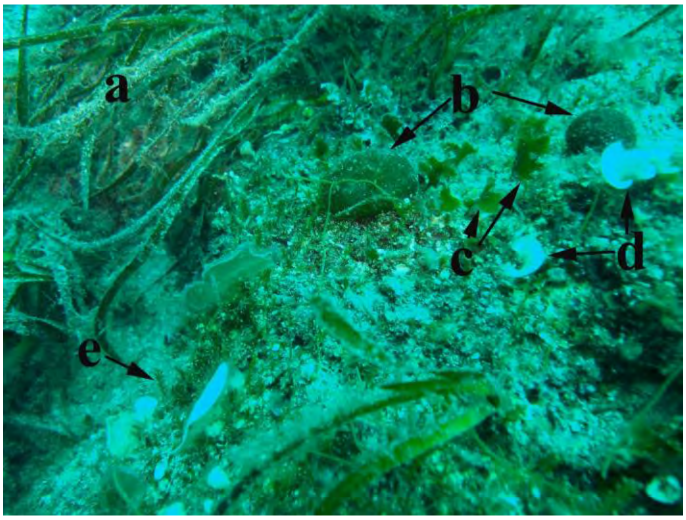

Figure 6. Macroalgal vegetation in the infralittoral zone from the Aegean coasts of Turkey (15 m, Ildır Bay, Turkey) (a: *Posidonia oceanica*, b: *Codium bursa*, c: *Flabellia petiolata*, d: *Padina pavonica*, e: *Caulerpa cylindracea*). (Photo: E.Taşkın).

Figure 7. The common brown alga *Padina pavonica* from the Aegean coasts of Turkey (15 m, Ildır Bay, Turkey). (Photo: E.Taşkın).

Figure 8. The coralligenousred alga *Mesophyllum alternans* from the Aegean coasts of Turkey (25 m, Ildır Bay, Turkey). (Photo: E.Taşkın).

Figure 9. The coralligenous red alga *Mesophyllum expansum* from the Aegean coasts of Turkey (30 m). (Photo: E.Taşkın).

3.4. Alien marine algae in the Aegean coast of Turkey

Alien and invasive marine macrophytes introduced into the Mediterranean Sea by aquaculture, by shipping, via Suez Canal, by fouling, by ballast water and by accidental escape from aquarium. Verlaque *et al.* (2015) reported 110exotic marine macrophytes species (71 Rhodophyta, 22 Phaeophyceae, 16 Chlorophyta and 1 Magnoliophyta) in the Mediterranean Sea.A list of accepted introduced marine macrophytes occuring on the coasts of Turkey was consist of 12 Rhodophyta (red algae), 13 Phaeophyceae (brown algae), 6 Chlorophyta (green algae) and 1 Magnoliophyta for a total of 32 taxa at specific and infraspecific level, 19 of which were reported from the Aegean coasts (Taşkın *et al*., 2011) (Table 6). Of them, the Phaeophyceae *Stypopodium schimperi* and the Chlorophyta *Caulerpa cylindracea* are common in Ildır Bay (the Aegean coasts of Turkey) and show aninvasive behaviour (Figures 10-11). Recently, the red alga *Asparagopsis taxiformis* is common in the Aegean coast of Turkey (Figure 12).

Figure 10. Exotic green alga *Caulerpa cylindracea* in the Aegean coasts of Turkey (10 m, Ildır Bay, Turkey). (Photo: E.Taşkın).

Figure 11. Exotic brown alga *Stypopodium schimperi* in the Aegean coasts of Turkey (15 m, Ildır Bay, Turkey). (Photo: E.Taşkın).

Figure 12. Exotic red alga *Asparagopsis taxiformis* in the north Aegean coasts of Turkey (26m, Gökçeada, Turkey). (Photo: B.Öztürk).

Table 6. Alien and invasive marine macrophytes on the Aegean coasts of Turkey. [M=Mediterranean; A=Atlantic; IP=Indo-Pacific; A=Alien; E=Established]

Taxa	Vector of introduction	Origin	Status	World distribution
Rhodophyta (red algae)				
Asparagopsis taxiformis(Delile) Trevisan de Saint-Léon	M	IP	E	Atlantic ocean, Pacific ocean and Indian ocean
Botryocladia madagascariensis Feldmann-Mazoyer	By Suez Canal	IP	E	Indian ocean
Falkenbergia rufolanosa (Harvey) Schmitz (Tetrasporophyteof *Asparagopsis armata* Harvey)	By fouling	IP	E	Atlantic ocean, Pacific ocean and Indian ocean
Hypnea spinella (C. Agardh) Kützing	By fouling	A, IP	E	Atlantic ocean, Pacific ocean and Indian ocean
Lophocladia lallemandii (Montagne) Schmitz	By Suez Canal	IP	E	Pacific ocean and Indian ocean
Rhodophysema georgii Batters	By aquaculture	A, IP	A	Atlantic ocean and Pacific ocean
Trailliella intricata Batters (Tetrasporophyte of *Bonnemasoinia hamifera* Hariot)	By fouling	IP	E	Atlantic ocean and Pacific ocean
Phaeophyceae (brown algae)				

Cladosiphon zosterae (J. Agardh) Kylin	By fouling	A	E	Atlantic ocean and Pacific ocean
Corynophlaea crispa (Harvey) Kuckuck	By fouling or balast water	A	A	Atlantic ocean
Ectocarpus siliculosus var. *hiemalis* (Crouan Frat *ex* Kjellman) T. Gallardo	By ship	A	A	Atlantic ocean
Halothrix lumbricalis (Kützing) Reinke	By fouling	A, IP	A	Atlantic ocean and Pacific ocean
Pylaiella littoralis (L.) Kjellman	By aquaculture	A, IP	E	Atlantic ocean, Pacific ocean and Indian ocean
Stypopodium schimperi (Buchinger *ex* Kützing) Verlaque *et* Boudouresque	By Suez Canal	IP	E	Atlantic ocean and Indian ocean
Chlorophyta (green algae)				
Caulerpa cylindracea Sonder	By ship	IP	E	Atlantic ocean and Indian ocean
Caulerpa taxifolia var. *distichophylla* (Sonder) Verlaque, Huisman & Procacini	Aquarium of Monaco	IP	E	Atlantic ocean, Pacific ocean and Indian ocean
Codium fragile subsp. *fragile* (Suringar) Hariot	By aquaculture	IP	E	Atlantic ocean and Pacific ocean
Codium parvulum (Bory ex Audouin) P.C.Silva	By Suez Canal	IP	E	Red Sea
Codium taylorii P.C.Silva	By ship or ballast waters	A, IP	E	Atlantic ocean, and Indian ocean
Ulva taeniata (Setchell) Setchell & N.L.Gardner	By ship	A	E	Atlantic ocean, Pacific ocean and Indian ocean
Magnoliophyta				
Halophila stipulacea (Forsskål) Ascherson	By ship	IP	E	Atlantic ocean, Pacific ocean and Indian ocean

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MARINE PHANEROGAMS (SEAGRASSES) OF TURKISH AEGEAN SEA

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1. Introduction

Seagrasses are evolved from land plants and adapted to the marine environment million years ago. They have roots, leaves, flowers, fruits, stems, which is called rhizome, like land plants. Reproduction involves a dominant sporophyte that features an elaborate reproductive organ the flower. Few of these higher plants are succesfull in the oceans. Spreading of the seagrasses are mainly with vegetative proliferation but also sexual reproduction can occurs. New areas are colonized by sexual reproduction (Borum *et. al.,* 2004). Seagrasses often form dense meadows on the sea floor due to the extensive vegetative propagation. Therefore they called Seagrasses. Ascherson (1871) probably was the first scientist to use the term "Seagrasses" or "Seegraser" to refer to the marine flowering plants ("phanerogame Meergewachse") in the scientific literature (Short *et al.,* 2001).

Seagrasses are aquatic angiosperms, which are adabted to the marine environment. There are 4 genus of marine phanerogams *(Halophila, Posidonia, Cymodocea, Zostera*) exists in the Mediterranean sea. The 50 species of marine phanerogams, which their ancestors were terrestrial, lives in the oceans. They evolved and adapted morphologicaly and anatomically to marine environment 200 million years ago. They are vascular plants. The conducting tissues (xylem and floem), support tissues and stomatas are diminished, pollination type specialized for marine environment therefore reproduction organs differentiated hereunder (Fischer *et al.* 1987, *in* Cirik and Cirik 1999).

Seagrasses provide oxygen by photosynthesis, trapped the sediments and suspended solid matter for water transparency by roots and rhizomes, provide nursery areas for marine animals, enhance the biodiversity of coastal waters, provide shoreline for erosion etc. The growth rates of seagrass rhizomes vary from a few centimeters per year to more than 5 m yr-1. As a result of these horizontal growing rates the slow growing species like *Posidonia oceanica* meadows can take centuries to cover a large area but on the other hand, the fast growing species like *Halophila* and *Cymodocea* it takes less than 1 year (Duarte, 2011).

Seagrasses grow and reproduce sexually being continuously submerged underwater. The reproductive cycle with flowering and pollination is completed in marine environment. Seagrasses have undergone many adaptations in order to adapt to the marine life. They rather efficiently take up inorganic carbon from the water, and the nutrients required for growth can be taken up by the roots, as for terrestrial plants, or from the water column through the leaves. The sediment at the bottom of the sea is most often without oxygen, the underground parts are supplied with oxygen from the leaves through a system of air-filled channels within the tissue.

Seagrass form extensive meadows, which are highly productive and often support high biomass, with a global average biomass of about 180 g C m-2 an average net production of about 400 g C m-2 yr-1, ranking amongst the most productive ecosystems in the biosphere. Seagrass bury about 27 Tg C year-1, or about 12% of the total carbon storage in marine ecosystems (Duarte, 2011).

There are paleontological evidences found about *Posidonia, Zostera and Cymodocea* genera were exists in Mediterranean Sea since tertiary time. However, the introduction of *Halophila stipulacea* is quite new. This species was introduced to Mediterranean Sea after the Suez Channel opened and spreading through the East Mediterranean Sea to Aegean and Western Mediterranean Sea. These species called "Lessepsian Species" are resistant to salinity variations (Cirik and Cirik, 1999).

In this chapter, the taxonomy and ecological characteristics, the distribution in the Aegean Sea, threats, the mapping of seagrasses ang legal measures are explained.

1. The Turkish Coast of Aegean Sea Seagrass Studies

Posidonia oceanica studies at the aegean sea; Pergent in 1985 was studied the flowering characteristics of *P. oceanica* at Urla; phenological an biochemical research was done by Cirik *et al.,* 1987. Biochemical and phenological researches has done by Haznedaroğlu, 1999; Haznedaroğlu and Akarsu, 2000; Haznedaroglu and Zeybek, 2000. In 1993-1994 some phenologic and depth limits of *P. oceanica* was studied in Sığacık (Dural and Pergent 2001; Dural 2010); Hoşsucu *et al.,*1997 was studied the damage of fishing methods on marine plants, Vegetation structure and lower limits of *P. oceanica* investigated in 52 sectors (Dural, 2003). The distribution and the level of genetic isolation of *Posidonia* meadows at Marmara Sea, the clonal diversity and the genetic affinity with other Mediterranean populations was studied in Meinesz *et al.,* 2009.Some phenelogical studies was carried out at 17 stations at the Aegean coast of Turkey to identify the status of *P. oceanica* meadows by Dural *et al.,* 2012. *P. oceanica* lower limits are generally 38-40 m in the Mediterranean and similar at Aegean sea depends on the transparency of the water. The phenological characateristics of *P. oceanica* on the coast of Aegean Sea of Turkey was given by Dural *et al*., 2013A. The lower limits of *P. oceanica* meadows vary from 8.5 m to 33 m. from inner part to outer part in Izmir Bay

(Dural *et al.*, 2013B). In Cirik and Akcali, 2013, the distribution of *P.oceanica* at at Marmara Sea was explained.

The distribution and the coverage of Marine Phanerogams were determined at Ayvalik Adalari Nature Park in the project of "Determination Work on Marine Biodiversity at Ayvalık Adaları Nature Park". The coverage of *P. oceanica* was 60% at the depths of 0-5m and 5-50m in 21 stations. *C. nodosa* was found in the shallow parts and coverage reaches to 90%. The introduced marine phanerogam species, *H. stipulacea* was not a significant distribution in the field, the coverage was 1-2%. The distribution of 3 seagrass species was given below at Figure 1 (Yokes and Demir, 2013).

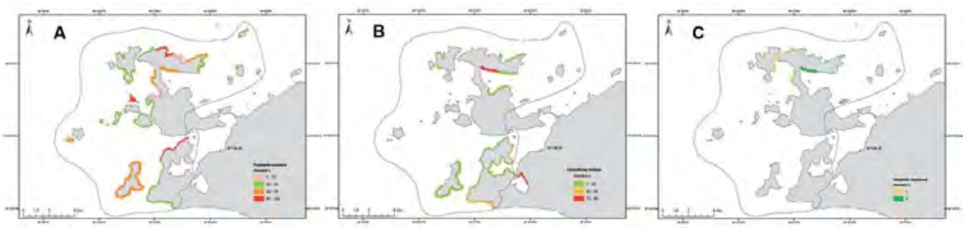

Figure 1. The distribution of marine Phanerogams at Ayvalik Adalari Nature Park; A. *Posidonia oceanica*, B. *Cymodocea nodosa*, C. *Halophila stipulacea* (Yokes and Demir, 2013).

The anchoring damage and coverage of *P. oceanica* meadows investigated with 309 scuba and 128 skin dives at 220 km coastline at Gokova Bay in 2005-2006. The coverage of the meadow was %61 at average and this coverage was decreased with the anchoring damage (Figure 2) (Okus *et al.,* 2010). Additionally, Okudan *et al.* 2011 was studied the anchoring damage at Fethiye-Göcek Specially Protected Area in 2008-2009 within 581 Scuba and 335 skin dives have been performed between 0.2 and 55 m depths. Both studies implies that anchoring is an important cause in *P. oceanica* degradation and has to be taken measures. Okus *et al.,*2007, determined the total coverage of *P. oceanica* meadows was 41.16 km^2 at Datça-Bozburun Specially Protected Area in 2002-2004. The anatomical features of *P. oceanica,*which was collected from the coast of Cesme (Aegean Sea), was investigated by Haznedaroglu and Akarsu, 2009. Phenological studies has been done in 1994-1995 at two depths (1-3 m; 4-7 m) by Dural, 2010 at Sığacık Bay (Aegean Sea İzmir-Turkey). The highest flowering density was found in January; fruits started maturing in February to April. Shoot density was found maximum (880 shoots/m^2) in December at 4-7 m. depth.

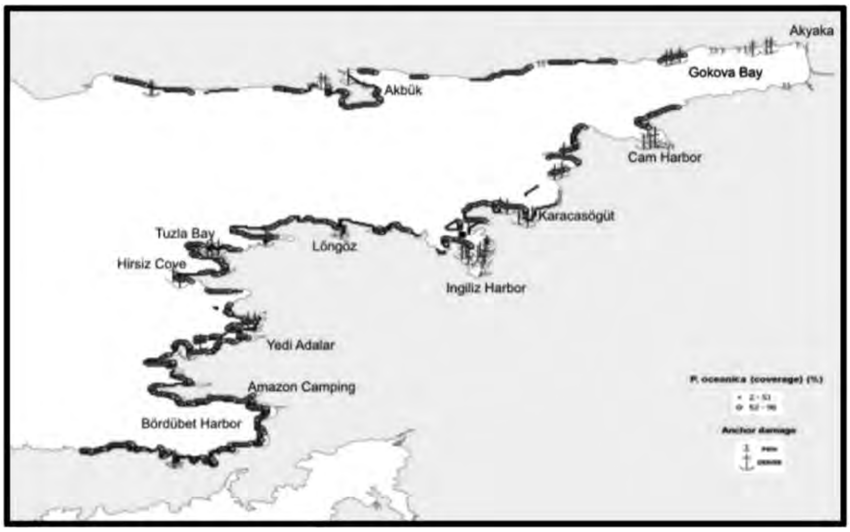

Figure 2. *P. oceanica* coverage and determined anchor damage along the coasts of Gokova SPA (Okus *et al.,* 2010).

Kocak *et al.,*2007, investigated the copper and zinc contaminations in sediment and *P. oceanica* at Engeceli Bay (Aegean Sea) in a fish farm to determine the impacts. The fish farming affect which is responsible for morphological changes of *P. oceanica* in Engeceli Bay (Aegean Sea) was studied by Kocak *et al.,* 2011. According to the results of the study; shoot density, leaf length, leaf surface, leaf area index and coefficient A values could be used as an indicator for variable environmental conditions.

Taskin, 2015; was used Ecological Evaluation Index (EEI) in Turkish coastal waters for the first time on marine macroalgae and seagrasses to assess the ecological status of the marine waters of Ayvalık (Aegean coast of Turkey). Taşkin and Öztürk, 2013; studied the macroalgal assamblages of *P. oceanica* at Marmara Sea and Ayvalık (Aegean coast of Turkey) and totally 87 taxa of macroalgae was found.

Çınar *et al.,* 1998; investigated the zoobenthos associated with *Zostera marina* at Gülbahçe Bay (Aegean Sea) in 1993-1994. Sampling was done at 3 stations at muddy-sand bottom covered with *Z. marina* at 0.5 m depth. As a result of this work 1906 individuals belonging to 108 taxa and 7 main taxonomic groups were counted. Polychaeta was the dominant group. Çınar, 2013; investigated the Polychaetes living with *P. oceanica* meadows along the coast of Turkey. 316 species reported from the Aegean coast of Turkey. Doğan *et al.,*2013; reported a review of Molluscs species associated with *P. oceanica* on the coast of Turkey. According to this publication 251 molluscan species live with *P. oceanica* meadows; Gastropoda (62%) and Bivalvia (32%) are the dominant classes of the Mollusca phylum along the Turkish coasts.

Katağan and Bakır, 2013; presented a publication on Crustaceans associated with *P. oceanica* on the coast of Turkey. Aegean coast of Turkey (66%) has the highest biodiversity about the crustaceans than Mediterranean (41%) and Dardanelles (22%). This is because of; Aegean Sea studied a lot and has a very long coastline. Açık, 2013; prepared a review on Sipunculans associated with *P. oceanica* on the coast of Turkey. Nine species of sipunculan species were reported on the Aegean coast of Turkey.

Dural *et al*., 2012; carried out a research on phenological changes by antrophogenic impacts in *Posidonia oceanica* meadows at Aegean Coast of Turkey. Samples collected from 17 stations at 8-10 m depths in 1999 by scuba diving. The description of the stations and shoot density classification of *P. oceanica* meadows was given Table 1.

Table 1. General description of the stations and shoot density classification of *P. oceanica* meadows (Dural *et al*.,2012).

Stations	**Region**	**Lat./Long.**	**Depth (m)**	**Temp. (^{0}C)**	**Sediment Type**	**Shoot Density Classification (Shoots.m^{-2})**
Ayvalık	North Aegean	39° 21' N 26° 35' E	10	14	Rock Sand	Normal (480)
Aliağa	North Aegean	38° 49' N 26° 56' E	9	15.5	Sand-Gravel	Supranormal (741)
Foça	North Aegean	38° 41' N 26° 44' E	9	14.5	Sand-Silt	Subnormal (307)
Hekim Island	Middle Aegean	38° 26' N 26° 46' E	10	17	Sand-Silt	Normal (507)
Inceburun	Middle Aegean	38 ° 24' N 26° 37' E	9	16	Sand-Silt	Abnormal (261)
Karaburun	Middle Aegean	38° 40' N 26° 26' E	8	14	Sand-Gravel	Supranormal (779)
Gerence	Middle Aegean	38° 28' N 26° 25' E	10	17	Sand-Silt	Supranormal (624)
Eşek Island	Middle Aegean	38° 36' N 26° 20' E	10	14.5	Sand-Gravel	Normal (416)
Çeşme	Middle Aegean	38° 20' N 26° 17' E	10	15.5	Sand-Gravel	Supranormal (848)
Alaçatı	Middle Aegean	38° 15' N 26° 23' E	10	14	Sand-Gravel	Normal (469)
Mersin Bay	Middle Aegean	38° 15' N 26° 25' E	10	14	Sand-Gravel	Normal (507)
Teke Cape	Middle Aegean	38° 05' N 26° 35' E	8	14.5	Sand-Gravel	Normal (496)
Sığacık Bay	Middle Aegean	38° 12' N 26° 40' E	10	16	Sand-Gravel	Supranormal (576)
Gümüldür	South Aegean	38° 01' N 27° 04' E	10	18	Sand-Gravel	Supranormal (817)
Kuşadası	South Aegean	37° 51' N 27° 14' E	8	20	Sand-Silt	Normal (576)
Turgutreis-Bodrum	South Aegean	37° 00' N 27° 14' E	10	19.5	Sand-Silt	Supranormal (667)
Paşatarlası-Bodrum	South Aegean	37° 01' N 27° 26' E	8	16	Sand-Silt	Abnormal (277

Cengiz and Cavas, 2010 was studied the use of dead *P. oceanica* leaves as an alternative low cost biosorbent to remove methyl violet (MV) from aqueous solutions. Cengiz *et al.,* 2012 made a research on dead *P. oceanica* leaves to remove the Astrazon Red which is used in textile industry from the waste waters. Pilavtepe *et al.,* 2012 was investigated the conver sion of *Z.marina* residues to bioethanol as an economical solution. Demir *et al.,* 2012, studied the biosorpsion of methylene blue by dead leaves of *P. oceanica* with artificial neural network model. As a result of this paper this method can be used alternative cheap absorbent but it has to be taken precautions nat to collect living leaves of *Posidonia*. Pilavtepe and Yesil-Celiktas, 2013; developed a mathematical model on supercritical fluid extraction of phenolic compounds from *P. oceanica* residues. Dural *et al*., 2011; studied on methylene blue adsorption of active carbon which was produced from dead leaves of *P. oceanica.* Pilavtepe *et al*., 2012; worked on the mathematical model of the phenolic compounds extraction from *Z. marina* residues using supercritical CO2 technology with changing parameters such as temperature, pressure and co-solvent ratio. As a result phenolic acids recovery were in good agreement with the experimental results but the assumption of the lumped system, which was employed for the particles, is much better at the final time than at the initial time. Pilavtepe *et al.,*2013; worked on potential of *P. oceanica* residues as a biofuel.

Gokce and Haznedaroglu, 2008; was published a paper about the efficacy of *P. oceanica* extract on antidiabetic effect. Haznedaroğlu and Zeybek, 2007; was determined the chicoric acid levels in leaves of *P. oceanica* with HPLC to understand the possibility of usage in the pharmaceutical sciences. Haznedaroğlu and Gökçe, 2014; investigated the effect of *Zostera noltii* extracts to lower blood glucose prevent hyperglycemia-induced endothelial dysfunction.

The wave attenuation of the *P. oceanica* meadows was studied by Elginoz *et al.,* 2011. The experiments were done at the laboratory with a 1:10 scale of *P. oceanica* meadow structure. As a result of this study *P. oceanica* meadows attenuates wave height and dissipates wave energy.

Alvarez-Varela *et al.,* 2011; investigated the molecular identification of the lessepsian immigrant seagrass species *H. stipulacea* from Izmir (Aegean Sea- Turkey).

2. Seagrasses of Aegean Sea

There are 5 seagrass species exits in Aegean Sea. These are; *Halophila stipulacea, Posidonia oceanica, Cymodocea nodosa, Zostera marina* and *Zostera noltii. H. stipulacea* is an introducea invasive seagrass species spreading from the Eastern Mediterranean to Western at the beginning of 20th century. It is an Lessepsian species which was coming from Suez Channel. *P. oceanica* is an endemic seagrass species to

Mediterranean. The phenological and ecological charecteristis was explained below according to the taxonomic order.

Halophila stipulacea **(Forsskal, 1775) Ascherson**

H. stipulacea is an euryhaline seagrass species. It grows in soft and muddy sediments in sheltered localities. *H. stipulacea* has been described as generally having a wide ecological range, growing from the intertidal to depths of greater than 50–70m (Lipkin,1979; Hulings, 1979; Beer and Waisel, 1982).Female flowers and fruits occurs from February to April in India, but in the Mediterranean the inflorosence season is in July to August and fruits ripening in September. *H. stipulacea* native distribution area is Red Sea and East Africa, Persian Gulf, to southwestern coast of India (Western Indian Ocean). However it is spreading in the Mediterranean Sea (Figure 3) (Levantine Sea, Southern Aegean, Turkey, Greece, Malta, Sicily, Tunisia) and recently at the Eastern Carribean (Galil, 2006; Akcali and Cirik, 2007; Gambi *et al.,* 2009, Willette *et al.,* 2014). Shoot density is extremely high, up to almost 19000 shoots/m^2 in shallow water (Procaccini *et al.,*2003).

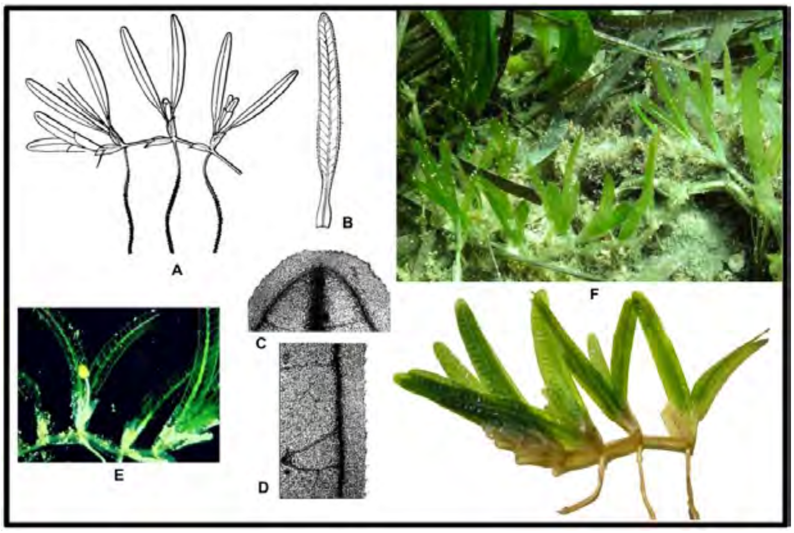

Figure 3. A. General view of *H. stipulacea* **B.** Leaf detail **C.** Apex detail of the leaf **D.** margin detail of the leaf, **E.** Flower **F.** Underwater photo

Posidonia oceanica **(Linnaeus) Delile, 1813:**

P. oceanica is the most important seagrass species in the Mediterranean Sea and covers the largest areas (Figure 4). This species exists between 11°C-29°C temperatures, salty and clean waters at 0-40m depths. The dead leaves of *P. oceanica* create banquets at the shoreline by currents and waves. These structures conserve the shoreline and prohibit the erosion besides a lot of marine species live by the help of these structures (Figure 4H). Seagrasses shelter a lot of epibiont species (Boudouresque and Meinesz, 1982; Cirik and Cirik, 1999).The seaweeds and invertebrates live on the leaves and rhizomes of *P. oceanica*. Some fishes and sea urchins fed on these organisms. Posidonia meadows well developed in shallow enclosed bays and their leaves reach to surface. This is called “posidonia reef” (Figure 5).

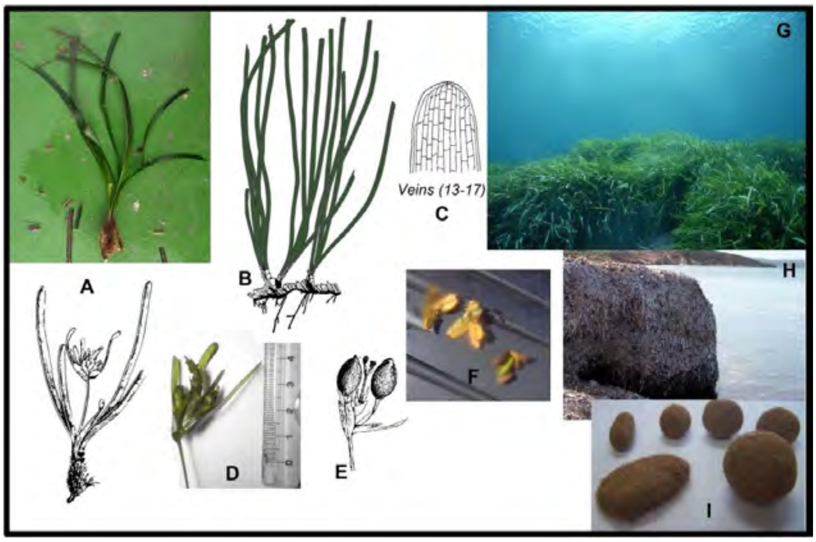

Figure 4. *P. oceanica*, **A.** General view, **B.** Rhizome, **C.** Apex detail of the leaf, **D.**Flower **E.**Fruit **F.**Fruits opened prior to dehiscence **G**. *P. oceanica* meadow, **H.** *P. oceanica* banquets **I.**aegagrophiles (Photos: B.Akcali, Drawings from FAO, 87).

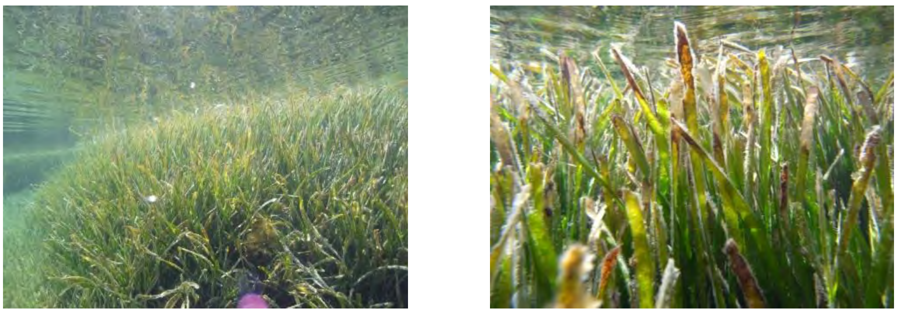

Figure 5. Posidonia reef (Photos by B. Akcali).

P. oceanica can live in salinities between 33- 39 psu (Gobert *et al*., 2006; Sanchez-Lizaso *et al*., 2008) and temperatures between 9°C and 29°C (Boudouresque and Meinesz 1982). Meinesz *et al.* (2009) found that *P. oceanica* is living in salinities between 21.5-28 psu at the Dardanelle Strait and Marmara Sea (Figure 9). These conditions are extraordinary for *Posidonia oceanica*. They could not spread under salinities 37 psu around the river mouths.

Cymodocea nodosa **(Ucria) Ascherson**

C. nodosa commonly occurs in shallow water (from a few cm to a depth of 2.5 m) but can reach a depth of 30-40 m, usually found in sandy substrate and sheltered sites. *C. nodosa* tends to grow in patches. This is because it favours unstable sandy sediments and subaqueous dunes tend to move over time. (Marba and Duarte, 1995). This species is a common seagrass in the eastern Mediterranean, frequently occurs in small sandy pockets. This species forms single species meadows in the Mediterranean Bioregion but also occurs in meadows with *P. oceanica* (it is out-competed by this species) (Short *et al*., 2007). Shoot density reaches almost 2000 shoots/m^2. It has classically been considered to be a pioneer species in the succession leading to a *P. oceanica* climax system. However it also grows in areas previously colonized by *P. oceanica* and characterized by dead matte (Procaccini *et al.,*2003).In addition recently *C. nodosa* grows with the alien invasive species *Caulerpa racemosa var. cylindracea* together in the same areas (Figure 6G) (personal communication. Baris Akcali 25.10.2015). *C. nodosa* meadows can have year-to-year fluctuations, sometimes they can disappear completely, but it can renew the meadow from the seed stocks in the sediment. *C. nodosa* can survive a moderate level of disturbance. *C.nodosa* provides important habitat for *Hippocampus. spp*. *C. nodosa* is found in the Mediterranean Sea and the adjoining parts of the Atlantic Ocean, the coasts of Portugal, Mauritania and Senegal and round the Canary Islands, Madeira and the island of Cape Verde (Figure 6) (Hartog and Kuo, 2006).

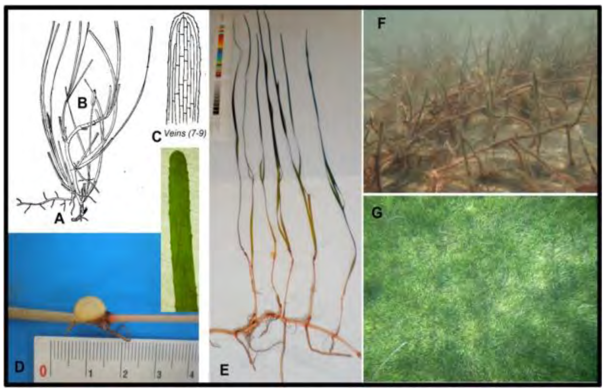

Figure 6. *C. nodosa,* **A, E.** General view, **B.** Flower, **C.** Apex detail of leaf, **D.** Seed, F,Underwater photo, **F.** underwater photo **G.** *Caulerpa racemosa var. cylindracea* with in the *C. nodosa* meadow. (Photos: B.Akcali, Drawings from FAO, 87).

Zostera marina Linnaeus, 1753:

Z. marina is considered to be a relict species in the Mediterranean, where it forms perennial meadows distributed from the intertidal to a few meters deep. It can grow on sandy and muddy substrate and is also present in lagoons, though it is rare throughout the Mediterranean. Shoot density in *Z. marina* beds is almost 1000 shoots/m^2 (Procaccini *et al.,* 2003). Studies on the genetic diversity of this species have never been performed in the Mediterranean (Figure 7).

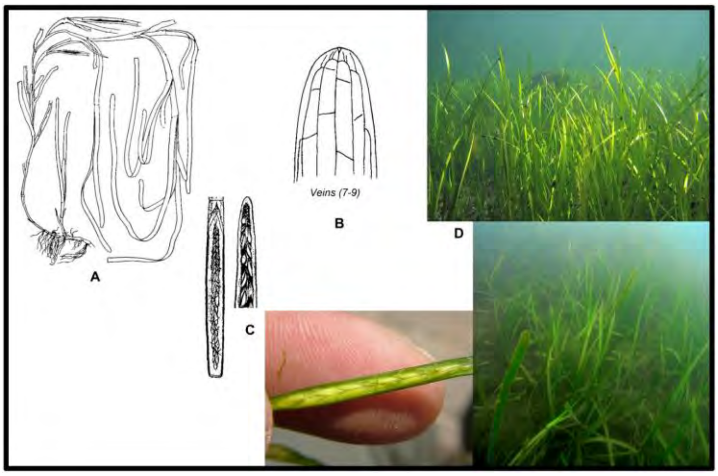

Figure 7. *Z. marina,* **A.** General view, **B.** Apex of the leaf, **C.** Seed and flower*, **D.** Underwater photo (Photos: B.Akcali, Drawings from FAO, 87). * http://www.aphotoflora.com/mon_zostera_marina_common_eel_grass.html

Zostera noltii Hornemann, 1832*:*

Z. noltii grows from the intertidal to depths of a few/ meters on sandy and muddy substrate. It is also present in enclosed and sheltered areas, where it can form mixed beds with *C. nodosa*, at densities up to almost 1300 shoots/m^2 (Procaccini *etal.,*2003).The coverage area of *Z. noltii* is restricted than *Z. marina* in the Mediterranean Sea (Figure 8).

2. Mapping and Distribution of Mediterranean Marine Phanerogams

Seagrasses spreading all around the world except Antartica (Björk *et al.,* 2008). According to Green and Short, 2003, the coverage of seagrass distribution area is 177.000 km^2, but this is a very rough estimation the area is tought to be much more than this. It is not certain because of the countries which are not determine the distribution area of seagrasses. A more exact determination of the global extent of seagrasses is difficult because most seagrass meadows have not been mapped and the cost of comprehensive mapping is high (Björk *et al.,* 2008).

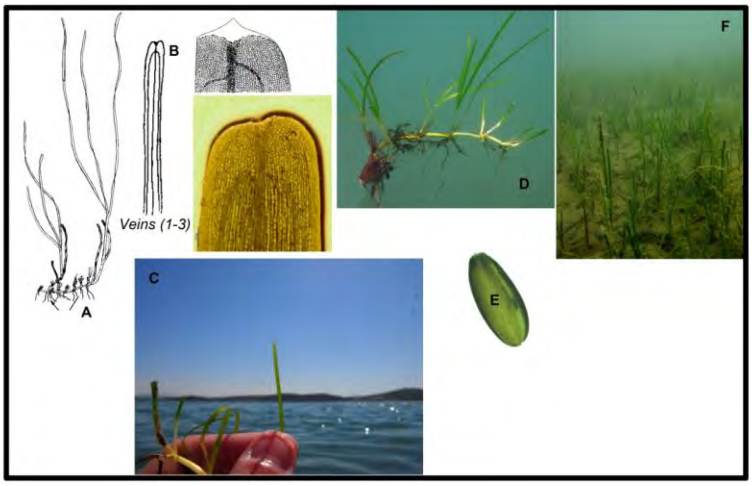

Figure 8. *Z. noltii,* **A.** General view, **B.** Apex detail of leaf **C.** Leaf detail, **D.** Rhizome and root detail, **E.** Seed (Meer Van Der W., 2009, **F.** underwater photo (Photos: B.Akcali, Drawings from FAO, 87).

Seagrass meadowscan be mapped with different techniques; satellite images to direct field studies. The choice of technique is scale, site and finance dependent. Especially satellite images and aerial photography has very precise results in shallow waters. Recently, acoustic devices (i.e. side scan sonar, multibeam echosounder) and remotely operated vehicles (ROV) have proved to be powerful tools in seabed mapping, allowing the production of accurate and detailed cartography, especially in the deeper waters. The development of new computerized tools such as Geographic Information System (GIS) software has facilitated the production of detailed and geo-referenced distribution maps of *P. oceanica* with a higher precision than previous works (Telesca *et al.*, 2015).

Initial mapping surveys may also provide the baseline information for monitoring programs. Such mapping surveys may be at various levels of detail, accuracy, and expense. Satellite and aerial imagery are useful for mapping dense seagrass meadows in the clear waters but they are not good at turbid or deep waters and sparse meadows. The selection of an appropriate scale is critical for mapping. Determining the level of detail required mapping an area also depends on the level of accuracy required for the final map product (McKenzie *et al.,* 2001).

P. oceanica distribution within the Mediterranean Sea is Alboran Sea at west side, Punta Chullera-Cala Sardina (Andalucia, Spain) at northern border, and the south border Sebkha-bou-Areg near Chaffarines Island (between Morocco and Spain). In particular, about the northeastern Mediterranean Basin boundaries of the *Posidonia* beds, contradictory information are available in the general descriptions of the repartition of this seagrass. It is mostly absent in the Dardanelles Strait and Sea of Marmara (Hartog, 1970, Fischer *et al.*, 1987, Boudouresque and Meinesz 1982). Recently, this species was found in the Sea of Marmara (Green and Short, 2003) without any precise information about this northeastern spot (a large point seems to indicate its presence in the west of Istanbul). In 2004, an isolated bed of *P. oceanica* was found in the middle and southern parts of the Sea of Marmara (Yuksek and Okus, 2004). Subsequently, *P. oceanica* was determined and mapped at Dardanelle Strait and South Marmara Sea (Pasalimani Island and Kapidag Peninsula) (Figure 9) with TUBITAK project called "Localisation of the northern east limits of the *P. oceanica* beds in the Turkish straits and the Marmara Sea Project No. 103Y18"has been done (Cirik *et al.,* 2007, *Meinesz et al., 2009*, Cirik and Akcali 2013).

Figure 9. **A.**Distribution of *P. oceanica* at Marmara Sea and Dardanelle Strait. **B.** Detail of Pasalimani island and Kapidag Peninsula.

Ünlüoğlu *et al.,* 2009; studied the habitats at Göcek Bay (SEPA), according to this study *P. oceanica, C. nodosa* and *H. stipulacea* mapped. *C. nodosa* spreading at 3-10 m. depths and covered the total area of 0,13 km^2, *P. oceanica* distribution was limited and spreading at 9-23 m depths and covered 0,05 km^2, *H. stipulacea* covered 0,075 km^2 (Figure 10).

Figure 10. **a.** Distribution of *C. nodosa* **b.** *P. oceanica*, **c.** *H. stipulacea* at Göcek Bay (Ünlüoğlu *et al.,* 2009).

P. oceanica monitoring activities started at 1980s in Mediterranean Sea. Since then this monitoring phenomena spreading all around the region. Two monitoring stations established at Foça (SEPA) (Hamamlık and Toprak Su Kampı) and the phenologic measurements had been made. The shoot density at Hamamlık was 173 shoot/m^2 and 181 shoot/m^2 at Toprak Su Kampı (Akçalı *et al.,* 2008). Another monitoring station had been placed at Aliağa in 2015. First phenologic measurements had been made recently (Akçalı *et. al.,* 2015).

3. Threats and Measures of Mediterranean Marine Phanerogams

Seagrasses are declining all around the world, because of anthropogenic effects and climate change etc. Therefore, mapping and monitoring activities should be done to see the trend on seagrasses. Seagrasses are good indicators for monitoring the marine ecosystem. Monitoring programmes has different aims and scales depending on needs. The first seagrass monitoring programmes started at the beginning of the 1980’s in Australia, USA and France. Recently more than 40 countries have developed seagrass monitoring programmes in more than 2000 meadows around the world. The most widely used parameters in seagrass monitoring programmes are the cover and density of seagrass meadows (Duarte *et al.,* 2004). Most of the monitoring programmes use direct observations on the field. It is effective to understand the situation but time and money consuming specially if the area is large. For this reason, if the area is big this method does not convenient. In this case, aerial photos, satellite images, aqustics can be used. Programs that assess changes across the entire meadows are far more effective in detecting trends than quadrat-based programs, which can only provide inferences on very local scales.

Since the 1970's, repetitive surveys of the seagrass beds became an important way to assess the general health of littoral water. They led to stress the relative importance of different causes of the major negative impacts such as the increase of turbidity due to different causes of pollution, definitive destructions of habitat by constructions on the sea, physical disturbance by fishing trawls, anchoring or use of explosives. More recently the effects of the global change on the hydrologic conditions of the Mediterranean Basin (temperature, salinity, currents) can affect the deepest and geographical boundaries of the *P.oceanica* beds and need a particular survey.

The causes which is listed above has been identified that, *P. oceanica* meadows increasingly disappearing and their dispersion limits are decreasing. Additionally, this plant grows very slowly (1-6 cm/year). Thus, maximum attention has to show to protect this species. The transplantation experiment has been done in Western Europe. But it is a difficult, time consuming and expensive work. The success from this work is not feasible. Assessment of transplantation success requires monitoring of the restored site, preferably for several years, and may therefore also be lengthy and costly. The monitoring survey may vary from species to species and from latitude to latitude (Borum *et al.,* 2004).

30-40% of the *P. oceanica* meadows has been lost in the Western Mediterranean Sea in last few decades because of human impacts. 18% of seagrasses lost all around the world in twenty years (Duarte *et al.,* 2008). According to Telesca *et al.* (2015) 1.5% of seagrass meadows is lost every year and almost 29% of the area extent of seagrass has last world wide since 1879 (Table 1).

Table 2. Spatial extent of *P.oceanica* meadows across the Mediterranean Sea.

	Mediterranean Sea	**Western basin**		**Eastern basin**	
Coastline length (km)	46,000	11,621	25%	34,379	75%
Coastline length with *P. oceanica* (km)	11,907	6,201	14%	5,706	12%
Coastline length without *P. oceanica* (km)	12,622	3,925	9%	8,697	19%
Coastline length without data (km)	21,471	1,494	3%	19,977	43%
Total area of *P. oceanica* (ha)	1,224,707	510,715	41.7%	713,992	58.3%

Because of the regression on *P. oceanica* meadows some precautions has to be made by countries. *P.ocenica* meadows are protected under the laws of “The European

Union's Habitat Directive (92/43/CEE)" "Barcelona Convention, under the "Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean", "Marine Strategy Framework Directive (MFSD) (2008/56/EC)" has established a framework according to which each Member States shall take the necessary measures to achieve or maintain "Good Environmental Status" in the marine environment. Angiosperms have been listed as a biological feature in Table 1 of Annex III "Indicative list of characteristics, pressures and impacts" and *P. oceanica* has been selected as representative species of the angiosperm quality elements for the Mediterranean marine environment. Parallel to this, each EU Member State has defined its own method to evaluate the health status of *P. oceanica* meadows according to the Water Framework Directive (2000/60/EC) (Telesca *et al*., 2015). Harvesting of *P. oceanica* and *Z. noltii* is prohibited according to the Fisheries Communique; 2012/65-66 of the Ministry of Food, Agriculture and Livestock.

Most of the population settled on the coastlines and linked to the marine environment. Therefore some measures should be taken to decrease the rate of seagrass loss; protective laws and policies, monitoring systems, public awarness, declared new marine protected areas.

The most important actions to prevent seagrass loss are: Control and treatment of urban and industrial sewage to reduce the loading with nutrients, organic matter and chemicals; Regulation of land use in catchment areas to reduce nutrient runoff and siltation due to soil erosion; Regulation of land reclamation, coastal constructions and downscaling of water exchange between open sea and lagoons; Regulation of aquaculture, fisheries and clam digging in or adjacent to seagrass beds; Create awareness of the importance of seagrasses and implement codes of conduct to reduce small-scale disturbances (Borum *et al.* 2004).

A wide range of management tools are available to prevent or reverse seagrass loss, but their efficiency and costs vary substantially, and remedial actions must be selected depending on the nature, source and strength of the human disturbance causing the loss of seagrass beds.

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PHYTOPLANKTON IN THE AEGEAN SEA: A REVIEW

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1. Introduction

Aegean Sea waters (ASW) are dramatically different from waters of the adjacent Ionian and Levantine Sea. Although the South Aegean Sea (SAS) is distinguished by its low nutrient values, primary production (PP) and phytoplankton, the North Aegean Sea (NAS) is comparatively more productive than the southern part (Siokou-Frangou *et al*. 2002). Exchanges between the Aegean Sea (AS) and the other Eastern Mediterranean waters (EMW) result in a limited supply of nutrients to the AS due to the inflow of the Levantine Intermediate Water (LIW) (Souvermezoglou *et al*., 1999). The Cretan Sea is the southernmost basin of the AS, and is the largest in volume and deepest (2500 m deep) (Georgopoulos *et al*., 1989, 2000; Theocharis *et al*., 1992, 1999). The southernmost basin of the AS is considered as one of the most oligotrophic systems in the worldwide, in terms of phytoplankton, chlorophyll *a* (chl-a) and nutrient concentrations (Berman *et al*., 1984a; Berman *et al*., 1984b; Azov, 1986; Yacobi *et al*., 1995). However, oligotrophy of the AS decrease to northward where there is more and more increase in nitrogen limitation, as it is reflected by a corresponding increase in the N/P ratio from 20 to 10 (Krom *et al*., 1991; Krom *et al*., 1992; Ignatiades, 1992, 1998, 2005; Ignatiades *et al*., 1995; Turkoglu *et al*, 2004a; Turkoglu, 2007; Turkoglu and Yenici, 2007a, 2007b). The structure of the pelagic food web which starts with phytoplankton in the Mediterranean Sea (MS), thereby in the AS can be separated temporally into two modes of operation. First mode, there is a late winter–early spring situation when there is a maximum in phytoplankton, PP and the resultant sedimentation of POC; attributable to a classical food chain dominated by diatoms, responding to nutrient pulses. The second mode is the late summer situation, when the dominant size class of organisms is small and forms the microbial loop, resulting in DOC accumulation and minimum sedimentation rates (Fowler *et al*., 1991; Thingstad and Rassoulzadegan, 1995). These characteristics combined with the development of certain mesoscale hydrographic features have led to the assumption that the AS, particularly southern area is an ideal place for determining the factors that control PP and phytoplankton (Margalef, 1985). On the other hand, the NAS is affected by the Black Sea Waters (BSW) via the Dardanelles (Canakkale Strait). Due to the nutrient and hereby phytoplankton interaction, the transport and spread model of less saline water of the BS origin into the surface layer of the NAS is important to understand in several aspects. Firstly, the thermohaline structure in large surface layer areas of the NAS is significantly affected by the discharge of the BSW. Secondly, the BSW is rather polluted and productive due to discharges from agriculture and industry and will thus also affect the water quality parameters such as phytoplankton, PP, chl-a and nutrient dinamics in the NAS (Jonsson, 2000, 2003; Turkoglu *et al*., 2004a, 2004b; Turkoglu, 2007; Turkoglu and Yenici, 2007a, 2007b). However, in the AS, very few phytoplankton and PP studies have been conducted so far (Becacos-Kontos 1968, 1973; Becacos-Kontos and Ignatiades, 1970; Koray, 1995; Koray *et al*., 1999a, 199b, 2000, 2001; Ignatiades, 1998, Turkoglu, 2004; Turkoglu, 2007). The scanty information available confirms that the ecosystem in the area is typically oligotrophic (Becacos-Kontos, 1977) with productivity levels similar to those of the pelagic waters of the Levantine Basin; The latter being considered to be the most oligotrophic region of the Mediterranean Sea (Azov, 1991).

The present study aims to uncover our knowledge on the qualitative and quantitative analyses of phytoplankton abundant, biomass, chl-a and PP of the AS, particularly Turkish coasts and offshore waters of the AS. Analyses of phytoplankton community structure and chl-a measurements are performed during the last 15 years (2000-2015). On the one hand, the main goal of the study is to determine the temporal and vertical variations in phytoplankton and associated phytoplanktonic parameters. On the other hand, phytoplankton differences between southern and northern basins of the AS is to record.

2. Methodology

As a methodology, the study on the phytoplankton rewiev in the AS is organized on qualitative and quantitative phytoplankton variations, and associated phytoplanktonic parameters such as chl-a, PP, nutrients and HABs in two different ecological zones which are seperated as the SAS and the NAS (Figure 1) due to the regional important temperature, salinity, nutrient and so phytoplankton differences.

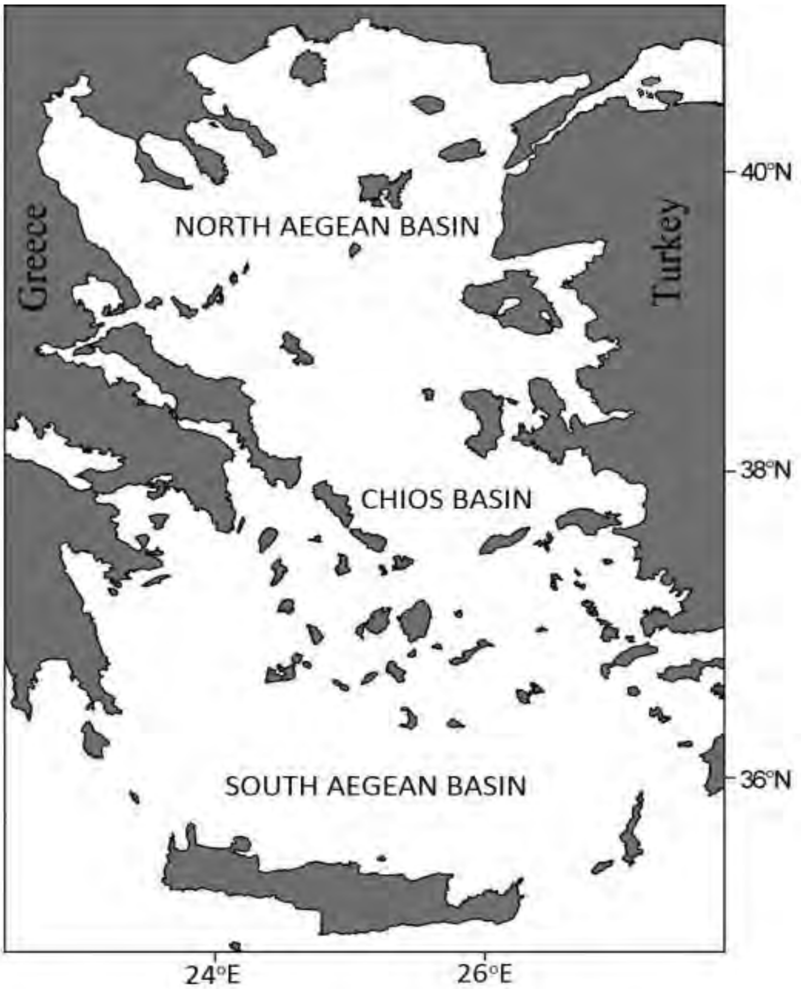

Figure 1. Aegean Sea and Basins

3. Phytoplankton in the Aegean Sea

3.1. Turkish phytoplankton research history in Aegean Sea

The research history in phytoplankton on the coast of the AS only extent to the beginning of the second half of the twentieth century (Nümann, 1955; Acara and Nalbantoğlu, 1960; Geldiay and Ergen, 1968; Gökalp, 1972). The research numbers on phytoplankton for the Turkish coasts of the AS in the following years are presented in Table 1.

Table 1. Research distribution on phytoplankton in the period of 1950 and 2015 in then Aegean Sea

Period	Research Number	Literatures
1950-1960	2	Numann, 1955; Acara and Nalbantoglu, 1960
1961-1970	2	Ergen, 1967; Geldiay and Ergen, 1968
1971-1980	3	Gokalp, 1972; Ober, 1972; Geldiay and Uysal, 1978
1981-1990	25	Gokpinar and Koray, 1983; Kideys *et al*., 1988; Koray and Gokpinar, 1983a, 1983b; Koray and Ozel, 1983a, 1983b; Buyukisik and Koray, 1984; Koray, 1984; Kocatas *et al*., 1984, 1986, 1987; Koray and Buyukisik, 1986, 1987; Koray, 1987a, 1987b, 1987c, 1988a, 1988b, 1988c; Koray and Buyukisik, 1987, 1988; Koray, 1990a, 1990b, 1990c; Koray *et al*., 1990
1991-2000	27	Koray, 1991, 1992a, 1992b, 1994, 1995; Koray *et al*., 1992a, 1992b, 1994, 1996, 1999a, 1999b; Koray and Buyukisik, 1992; Kocataş *et al*., 1992; Buyukisik *et al*., 1994, 1997; Parlak *et al*., 1994; Koray and Kesici, 1994; Buyukisik, 1995; Koray *et al*., 1996; Bizsel *et al*., 1997; Koray and Kocatas, 1997; Olcum and Gokpinar, 1997; Buyukisik *et al*., 1997; Metin and Cirik, 1999; Koray *et al*., 1999a, 1999b; Balkis, 2000
≥ 2001	29	Balkis and Koray, 2001; Koray *et al*., 2001; Balkis and Koray, 2001; Bargu *et al*., 2002; Koray, 2001, 2002a, 2002b, 2002c; Koray and Cihangir, 2002; Bizsel and Bizsel, 2002; Polat and Koray, 2002a, 2002b; Koray and Colak-Sabanci, 2001, 2003; Colak-Sabanci and Koray, 2005; Koray *et al*., 2007; Balkis, 2005, 2008, 2009; Balkis and Balci, 2009; Turkoglu *et al*., 2004a; Turkoglu, 2007; Aktan, 2011; Altug *et al*., 2011; Ciftci, 2011; Aglac and Balkis, 2014; Guresen and Aktan, 2014; Tas, 2014; Yurga, 2015

Since the first research on phytoplankton in the 1955 (Numann, 1955), when evaluated research numbers in 10 yearly periods in the AS, there are 2, 2, 3, 25, 27 and

29 researh number on phytoplankton in the period of 1950-1960, 1961-1970, 1971-1980, 1981-1990, 1991-2000 and 2001-2015, respectively (Table1).

3.2. Phytoplankton community structure and composition in the Aegean Sea

Phytoplankton composition and percentage distributions between upper taxonomic groups according to check list of Koray *et al*. (1999a, 1999b) and Koray (2001) in all Turkish Seas and comperative analyses of phytoplankton in the AS together with other Turkish Seas such as BS and North Levantin Sea (NLS) are presented in Table 2 and 3, respectively. Moreover, phytoplankton composition and percentage distribution in the period of March 2002 and December 2003 in the NAS (Saros Bay) is given in Table 4.

Table 2. Phytoplankton composition and percentage distributions according to check list of Koray *et al*. (1999a, 1999b, 2000) and Koray (2001)

Taxonomic Group	Genus	Species	Variety	Forma	Taxa	f(%)
Cyanophyceae	6	7	0	0	7	1.42
Dinophyceae	31	185	43	7	235	47.75
Prymnesiophyceae	4	4	0	0	4	0.81
Chrysophyceae	1	1	0	0	1	0.21
Dictyochophyceae	2	3	4	0	7	1.42
Xanthophyceae	1	1	0	0	1	0.21
Bacillariophyceae	67	214	8	3	225	45.73
Euglenophyceae	2	2	0	0	2	0.41
Prasinophyceae	4	7	0	0	7	1.42
Chlorophyceae	1	2	0	0	2	0.41
Incartae sedis	1	1	0	0	1	0.21
Total Phytoplankton	**121**	**431**	**51**	**10**	**492**	**100**

In all Turkish Seas, it is identified total 396 phytoplankton species which contain 1 species Cyanophyceae, 193 species Dinophyceae, 2 species Prymnesiophyceae, 1 species Chrysophyceae, 7 species Dictyochophyceae, 1 species Xanthophyceae, 179 species Bacillariophyceae, 2 species Euglenophyceae and 7 species Prasinophyceae by Koray *et al*. (2000). A total 492 phytoplankton taxa (7 procaryotes and 485 eucaryotes taxa) have been reported in the various studies in the Turkish Seas since the beginning of the second half of the 20th century. According to the check list of Turkish seas plankton updated continuously (Koray *et al*, 1999a; 1999b; Koray, 2001), it was listed total 492 phytoplankton species which contain 7 species Cyanophyceae (1.42%), 235 taxa Dinophyceae (47.75%), 4 taxa Prymnesiophyceae (0.81%), 1 taxa Chrysophyceae (0.21%), 7 taxa Dictyochophyceae (1.42%), 1 taxa Xanthophyceae (0.21%), 225 taxa Bacillariophyceae (45.73%), 2 taxa Euglenophyceae (0.41%)and 7 taxa Prasinophyceae

(1.42%), 2 taxa Chlorophyceae (0.41%) and 1 incartae sedis (0.21%). On the other hand, according to Koray (2001) although dinoflagellates *Gonyaulax tamarensis* (=*Alexandrium tamarense*), *Gymnodinium* cf. *mikimitoi (=Karenia mikimitoi),* diatoms *Nitzschia seriata* (=*Pseudonitzschia seriata*) and *Heterosigma* cf. *akashiwo* were reported by varios researchers (Fevzioğlu and Tuncer, 1994; Bizsel and Bizsel, 2002), these species were not valid due to the insufficient local sistematic data and diagnosis on these species (Koray, 2001).

Table 3. Phytoplankton composition and percentage distribution in the period of 30 December 1995 and 05 November 1997 in the Aegean Sea comparative with Black Sea (BS), Aegean Sea (AS), North East Mediterranean Sea (MS) (Koray *et al*., 2000).

Groups	**Genus**			**Species**			**Forma-Variety**			**Taxa**			**f(%)**
Groups	**BS**	**AS**	**MS**	**BS**	**AS**	**MS**	**BS**	**AS**	**MS**	**BS**	**AS**	**MS**	**AS**
Cyanophyceae	1	1	1	0	0	0	0	0	0	1	1	0	**0.41**
Dinophyceae	11	20	17	72	103	80	15	30	27	87	133	107	**54.7**
Prymnesiophyceae	2	2	0	2	2	0	0	0	0	2	2	0	**0.83**
Dictyochophyceae	2	2	1	4	2	1	2	2	0	6	4	1	**1.65**
Bacillariophyceae	31	37	37	86	94	79	5	8	8	91	102	87	**42.0**
Euglenophyceae	0	0	0	0	0	0	0	0	0	0	0	0	**0.00**
Prasinophyceae	0	1	1	0	1	1	0	0	0	0	1	1	**0.41**
Chlorophyceae	0	0	0	0	0	0	0	0	0	0	0	0	**0.00**
Total Phytolankton	**47**	**63**	**57**	**164**	**202**	**161**	**22**	**40**	**35**	**187**	**243**	**196**	**100**

In view of phytoplankton diversity richness, the comperative results between different Turkish Seas are presented in Table 3. According to the results, the richest region in phytoplankton diversity between Turkish Seas in view of Dinophyceae and Bacillariophyceae which are the most important two class groups of phytoplankton is the AS and it is followed by the BS and MS. On the other hand, when look at the percent proportions between different taxonomic groups especially in terms of Dinophyceae and Bacillariophyceae, the proportion or contribution of dinoflagellates (133 taxon; 54.7%) to total phytoplankton (total 243 taxa) is higher than diatoms (102 taxa; 42.0%) and other (7 taxa; 3.30%) (Table 3). Considering the oligotrophic level of AS, the proportion between diatoms and dinoflagellates should be the advantage of diatoms. However, although the Izmir Bay is a part of the oligotrophic AS, it is eutrophic due to the domestic and industrial discharges. Therefore, the proportion between diatoms and dinoflagellates change to the disadvantage of diatoms in the Izmir Bay. Although the Saros Bay is located in the NAS, the proportions in different phytoplankton groups each other in the Bay are the advantage of diatoms (Turkoglu *et al*., 2004a; Turkoglu, 2007a) unlike the Izmir Bay (Koray *et al*., 2000). For example, while the proportion of diatoms to total phytonkton in the SAS (Izmir Bay) is 39.3%, the propotion in the NAS (Saros Bay) is 55.3% (Table 4). In other study, there is a smilar trend in percentages between diatoms (61%) and dinoflagellates (39%) (Guresen and Aktan, 2014). It is known that oligotrophic level decrease from the south to the north in the Aegean Sea (Krom *et al*., 1991; Krom *et al*., 1992; Ignatiades, 1998, 2005; Turkoglu *et al*, 2004a; Turkoglu, 2007; Turkoglu and Yenici, 2007a, 2007b).

There is also a similar trend in view of phytoplankton cell densities in the AS. For example, while average surface phytoplankton abundance (cell density) is under 1.00 x10^5 cells L^{-1} in offshore waters of the SAS (Ciftci, 2011; Aglac and Balkis, 2014), the cell densities of phytoplankton is over 1.00 x10^6 cell L^{-1} in the coastal waters of the NAS (Saros Bay) (Turkoglu *et al*., 2004a; Turkoglu, 2007). In the Saros Bay, phytoplankton cell density is higher in spring period (May 2002 and April 2003) than other periods like in the other MS basins. Total phytoplankton cell density is ranged from 1.0x10^6 to 8.0x10^6 cells L^{-1} except for regions under effect of the Dardanelles and the Meriç river (1.0x10^7-3.0x10^7 cells L^{-1}) in productive or bloom periods such as spring (March-May, 2002), late summer (August, 2003), early winter periods (December, 2003) (Figure 2) (Turkoglu *et al*., 2004a; Turkoglu, 2007).

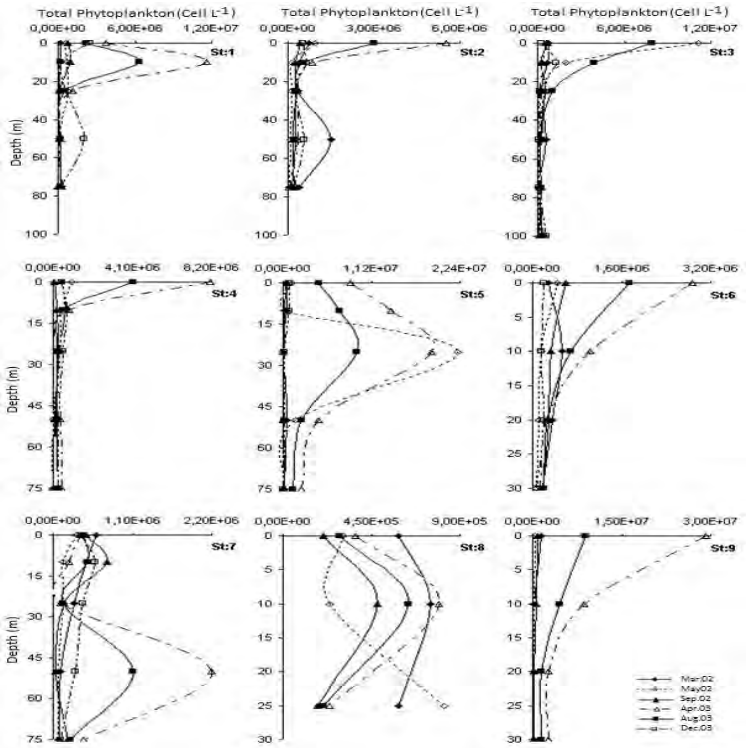

Figure 2. Seasonal and vertical distributions of phytoplankton cell densities in the period of March 2002 and December 2003 in the NAS (Saros Bay) (Turkoglu *et al*., 2004a; Turkoglu, 2007)

According to qualitative analyses of phytoplankton in the NAS based on the Saros Bay, phytoplankton diversity is lower than in the SAS (Izmir Bay) (Koray *et al*., 2000, Koray, 2001). Turkoglu *et al*. (2004a) reported that it is identified 174 phytoplankton species belonging to 63 genera in NAS (Saros Bay). They include 1 taxon Cyanophyceae (cyanobacteria) and 1 taxon Prymnesiophyceae (coccolithophore), 2 taxa Euglenophyceae, 2 taxa Chlorophyceae (green algae), 6 taxa Dictyochophyceae (silicoflagellate), 66 taxa Dinophyceae (dinoflagellates) and 96 taxa Bacillariophyceae (diatoms). Among the phytoplankton groups, diatoms and dinoflagellates compose 55.3% and 37.9% of the total phytoplankton, respectively (Table 4) (Turkoglu *et al*., 2004a; Turkoğlu, 2007). Turkoglu *et al*. (2004a) and Turkoglu (2007) revealed that diatoms are more abundant than dinoflagellates in middle winter (January) and late summer periods (July and August 2003), whereas both are dominant in early winter (December and January) and early spring periods (March and April) in NAS (Saros Bay). Additionally, coccolithophores are dominant in May and June in the NAS (Turkoglu *et al*., 2004a; Turkoglu, 2007). Similar results on percentages of phytoplankton groups are revealed by Çiftci (2011). He showed in the AS in middle autumn (October, 2000) that while dinoflagellates display an important ecological role in terms of species diversity, diatoms display the important role in view of phytoplankton biomass (71.0%) in the AS. Besides, in terms of cell density the second most abundant phytoplankton groups are coccolithophores (mainly *E. huxleyi*) (39.0%) and small silicoflagellates (32.0%) in the AS (Ciftci, 2011).

Tablo 4. Phytoplankton composition and percentage distribution in the period of March 2002 and December 2003 in the NAS (Saros Bay) (Turkoglu *et al*., 2004a; Turkoglu, 2007)

Taxonomic Group	Genus	Species	Variety	Forma	Taxa	f(%)
Cyanophyceae	1	1	-	-	1	0.57
Dinophyceae	17	52	12	2	66	37.9
Prymnesiophyceae	1	1	-	-	1	0.57
Dictyochophyceae	2	3	3	-	6	3.45
Bacillariophyceae	39	87	7	2	96	55.3
Euglenophyceae	2	2	-	-	2	1.15
Chlorophyceae	1	2	-	-	2	1.15
Total Phytoplankton	**63**	**148**	**22**	**4**	**174**	**100**

On the other hand, there are signs that claims to the contrary findings stated above. For example, Altug *et al*. (2011) showed that from total of 103 taxa belong to seven algal classes, dinoflagellates (51.0%) are more important than diatoms (37.0%) in terms of species number in the NAS (Altug *et al*., 2011). A similar result to the detriment of diatoms (Dinoflagellates: 53.7%; Diatoms: 43.9%) has been revealed in the Edremit Bay in the period of 2003-2004 by Aglac and Balkis (2014).

In terms of the contribution to the phytoplankton checklist (396 taxa) (Koray *et al*., 2000), the AS is lower (7 taxa; 1.77%) than the BS (45 taxa; 11.4%) and MS (9 taxa; 2.27%). Although 396 phytoplankton taxa were distinguished in Turkish Seas, only 73 taxa (18.4%) are common for all Turkish Seas. It is known that, temporal variations is more important than spatial variations for phytoplankton studies in Turkish Seas (Koray *et al*., 2000; Turkoglu, 2010; Turkoglu and Erdogan, 2010). Therefore, in order to enrich species diversity and to monitor density differences studies on phytoplankton should be organized in very short time periods such as a week, two weeks and even daily intervals.

3.3. Phytoplankton Groups

At the first glance, the results obtained from different studies shows the dominance of the picophytoplankton groups as the fingerprint of the AS due to the oligotrophic character. In such areas, cyanobacteria and picoeukaryotes often found together or alternate with diatoms, dinoflagellates and other flagellates belonging to different phytoplankton groups. The strong seasonality prevailing the basin also creates optimal environmental conditions for the alternation of phytoplankton populations dominated by different taxonomic groups and species (Goericke, 1998; Venrick, 2002; Siokou-Frangou *et al*., 2010). Therefore, the following sections are presented in order to uncover the ecological roles of different ecological groups of phytoplankton in two different basin (the SAS and the NAS) of the AS.

3.3.1. Picoplankton

Phytoplankton components smaller than 5.00 μm, commonly defined as picoplankton, is mainly constituted of the dominance of cyanobacteria, prochlorophytes and flagellates generally smaller than 5.00 μm (Yacobi *et al*., 1995; Ignatiades *et al*., 2002; Casotti *et al*., 2003; Brunet *et al*., 2007; Tanaka *et al*., 2007). Average picoplankton accounts for 59.0% of the total chl-a and 65.0% of the PP for all basin (Magazzu and Decembrini, 1995). However, PP values widely change depending on the seasons, regions and depths as well as on different methods used and size fractions considered. The AS highly dynamic mesoscale structures and picoplankton dominates the upper water layers through most of the year in March and September. Picoplankton is often dominant also in the depth of deep chl-a maksimum (DCM) in the AS (Ignatiades *et al*., 2002) like in the Mediterranean Western Basin (Marty *et al*., 2002). The prokaryotic picoplanktonic species, *Synechococcus* and *Prochlorococcus*, can surpass values of 10^7 cells L^{-1} (Zohary *et al*., 1998; Christaki *et a*l., 2001). Moreover, prochlorophytes are most often found in deeper layers in stratified conditions (Yacobi *et al*., 1995) with a dramatic peak near the compensation depth (Christaki *et al*., 2001), while they become abundant at surface in autumn/winter period (Marty *et al*., 2002).

However, prochlorophytes have been found to be abundant in surface waters even in summer (Vaulot *et al*., 1990).

In addition to prokaryotic picoplankton, quite a high eukaryotic picoplankton diversity including prasinophytes, prymnesiophytes and chrysophytes may be found in the AS. Based on epifluorescence microscopy counts, autotrophic and heterotrophic organisms smaller than 3.00 µm are dominant (in the order of 10^6–10^7 cells L^{-1}, about 75.0% of the <10 µm size fraction) throughout the MS in June 1999 (Christaki *et al*., 2001). Various non-colonial picoplanktonic diatoms such as some species of *Chaetoceros*, *Thalassiosira*, *Minidiscus* and *Skeletonema* are also abundant in some cases (Delgado *et al*., 1992).

3.3.3. Nanoplankton

Phytoplankton components between 5.00 and 20.0-50 µm, commonly defined as nanoplankton, is mainly constituted of flagellates generally bigger than 5.00 µm and dinoflagellates, mostly naked dinoflagellates, in addition to coccolithophores and a litle small solitary diatom species. In many cases, colonial diatom cells are also smaller than 20.0 µm. Small nanoflagellates are the dominant group in view of cell densities in almost all year in the oligotrophic MS waters (Revelante and Gilmartin, 1976; Malej *et al*., 1995; Totti *et al*., 1999; Decembrini *et al*., 2009). However, there are several evidences that nanoflagellates do show regional and temporal variations and may also contribute significantly to phytoplankton blooms in the AS (Ignatiades *et al*., 1992, 1995, 2002) as in other basin of the MS such as the Catalan Sea (Margalef and Castellvi, 1967) and Western Mediterranean Sea (Marty *et al*., 2002).

Prymnesiophytes represent a large part of nanoflagellates in most of the year (Marty *et al*., 2002). Among them, the coccolithophores deserve a special mention, as they show a high diversity in the MS and the AS (Cros and Fortuno, 2002). The widespread species *Emiliania huxleyi* is generally the most frequent and dominant species in this group. Coccolithophores form an important population in both autumn and winter in the SAS as in Rhodos gyre area (Gotsis-Skretas *et al*., 1999; Malinverno *et al*., 2003) and in the NAS (Ignatiades *et al*., 1995). An important proportion of coccolithophores has been also reported in spring in the AS (Ignatiades *et al*., 2002; Turkoglu *et al*., 2004a; Turkoglu, 2007). A trans-Mediterranean study in June 1999 revealed that coccolithophores are more abundant at eastern stations than at western ones of the MS (Ignatiades *et al*., 2009). However, there is little information on the diversity and distribution of non-calcifying prymnesiophytes such as *Chrysochromulina* spp. and *Imantonia* spp.

Cryptophytes, often only detected by their marker pigment alloxanthin, are generally more abundant when diatoms are also abundant in winter and spring in the

Cretan Sea (Gotsis-Skretas *et al*., 1999). *Plagioselmis prolonga* is one of the most frequently mentioned species in this group (Cerino and Zingone, 2007). On the other hand, nanoplanktonic silicoflagellates (Dictyochophyceae) such as *Dictyocha fibula* var. *messanensis*, *D. polyactis*, *D. speculum* are found almost during the year in the NAS (Turkoglu *et al*., 2004a; Turkoglu, 2007).

As for nanoplankton representatives of dinoflagellates, they mainly include naked autotrophic and heterotrophic species. They are poorly known and can not identify in light microscopy. All information about these nano-dinoflagellates derives from microscopic counts, based on which they are less abundant than flagellates but much larger and hence more important in terms of biomass, especially in late spring and summer. In the AS, dinoflagellates are reported to be dominant in different seasons and especially in stratified conditions (Gotsis-Skretas *et al*., 1999; Psarra *et al*., 2000; Ignatiades *et al*., 2002). Some small thecate species such as *Prorocentrum minimum* and *P. balticum*, *Heterocapsa triquedra* and *Scrippsiella* t*rochoidea* are also part of the nanoplankton. Although they are generally not abundant in the AS offshore waters, they are generally abundant in coastal waters in the all year. For example, in the NAS (Saros Bay) small dinoflagellate species such as *Protoperidinium granii*, *P. steinii*, *Pyrophacus horologium*, *Scripsiella trochoidea*, *Prorocentrum balticum*, *P. compressum P. micans*, *P. minimum*, *P. scutellum*, *Dinophysis acuminata*, *D. caudata*, *D. fortii*, *D. rotundata*, *D. rudgei*, *D. sacculus*, *Diplopsalis lenticula*, *Heterocapsa triquetra, Scripsiella trochoidea* are found continuously during the year (Turkoglu *et al*., 2004a; Turkoglu, 2007).

3.3.4. Microplankton (Diatoms)

Phytoplankton components between 50 and 500 µm, commonly defined as microplankton, is mainly constituted of large diatoms, dinoflagellates and one celled microzooplankton species generally bigger than 50 µm. Large colonial diatom cells of the AS will evaluate in this section.

The main rule that the contribution of piconanoplankton decreases along with the increase of chl-a concentration (Li, 2002). In such a case, microplanktonic and colonial diatom genera larger than 20 µm such as *Asterionellopsis*, *Chaetoceros*, *Pseudo-nitzschia*, *Thalassionema*, *Thalassiosira* etc. are more dominant. A diatom increase is evident in the EMS (Wassmann *et al*., 2000; Gacic *et al*., 2002) in February-March, confirming the consistent anticipation of the spring bloom as “the unifying signature” of the basin (Margalef and Castellvi, 1967; Duarte *et al*., 1999). However, these algal bloom events are very temporary and hence during the year the blooms not record in offshore waters. Some diatom blooms occur in January and March and reached to 40-60% of the total phytoplankton in the Cretan Sea (Gotsis-Skretas *et al*., 1999), and 75-100% in coastal stations (Psarra *et al*., 2000; Turkoglu *et al*., 2004a; Turkoglu, 2007). In addition to during the winter bloom, diatoms also dominate in late spring (May) and late summer periods (August), and in subsurface layers such as deep convection areas for longer periods. Colonial species belonging to the genera *Pseudo-nitzschia, Leptocylindrus* spp. *Pseudosolenia calcar-avis, Rhizosolenia* spp*., Dactiliosolen fragilissimus* and *Chaetoceros* are most dominant in spring in deep convection areas of the AS. They are generally the main contributors also to high chl a patches in fronts and gyres (Fiala *et al*., 1994; Arin *et al*., 2002; Ignatiades *et al*., 2002; Zervoudaki *et al*., 2006, 2007). Diatom-dominated chl-a peaks are frequently found in subsurface layers (Arin *et al*., 2002), as in the exceptional case of a monospecific bloom of a *Thalassiosira* sp. forming gelatinous colonies (10^7 cells L^{-1} and 23 µg chl a L^{-1}) in the WMS (Gould and Wiesenburg, 1990). The formation and dynamics of these deep accumulations are strictly linked to the frontal circulation (Raimbault *et al*., 1993) and therefore are quite different from those characterizing the development of a DCM in the stratification period in oligotrophic waters. Algal blooms are such biological events that they are strictly depend on climatic and hydrodynamic variations and therefore they are spatially heterogeneous, and reveal a very high temporal dynamic, as well as a clear interannual variability (Mercado *et al*., 2005).

An important contribution of diatoms to phytoplankton in DCMs is reported in the Cretan Sea (Gotsis-Skretas *et al*., 1999). Frequently, the species involved are those that are also typical of the high production events described above, supporting the hypothesis that the DCMs are sites of active growth, rather than of passive accumulation (Kemp *et al*., 2000). In the DCM, diatoms are found in association with picoplankton and they also dominate the subsurface populations (Decembrini *et al*., 2009; Boldrin *et al*., 2002). Colonial *Chaetoceros* species are a rather constant feature of diatom-dominated DCMs, but the accompanying assemblages seem to vary from the south to the north. However, while *Bacteriastrum*, *Hemiaulus* and *Thalassionema* genera are found in the south of Crete (Berland *et al*., 1987), *P. delicatissima*, *Dactyliosolen fragilissimus*, and *Thalassionema frauenfeldii* were found in June in the north of Crete (Gotsis-Skretas *et al*., 1999). For example, in northmost of the AS *Cylindrotheca closterium, Dactyliosolen fragilissimus*, *Leptocylindrus danicus*, *L. minimus, Pseudo-nitzschia delicatissima*, *P. pungens*, *Pseudosolenia calcar-avis, Proboscia alata, Rhizosolenia* spp. such as *Rhizosolenia delicatula*, *R. fragilissima*, *R. hebetata* var. *semispina*, *R. setigera*, *R. stolterfothii* and *Thalassionema nitzschioides,* some *Thalassiosira* spp. such as *Thalassiosira rotula* form algal blooms in the very productive periods (Turkoglu *et al*., 2004a, Turkoglu, 2007). These differences in species composition are remarkable in the AS. While the above mentioned species often appear in relatively high concentrations, other large-sized diatoms are found at much lower concentrations in the offshore waters. In fact, these large diatoms have been reported as responsible for a substantial but underestimated fraction of primary production in oligotropic waters characterized by a strong seasonal thermocline and nutricline outside the MS (Goldman, 1993).

3.3.5.Other microplankton (Dinoflagellates)

The diversity of microplanktonic dinoflagellates is very high in the MS (Marino, 1990; Gomez, 2006), although their importance in view of abundance is rather low and their ecological role is still under assessment. With the exception of the high productivity events by diatoms mentioned in just other section, dinoflagellates are generally more abundant than diatoms in the size fraction higher than 20 μm (Marty *et al*., 2009). The species most commonly reported are those of the genera *Gymnodinium*, *Gyrodinium*, *Neoceratium* (formerly *Ceratium*), *Protoperidinium*, *Oxytoxum*, which are generally associated with warm and stratified waters (Estrada, 1991). Very rarely the percentage contribution of microplanktonic dinoflagellates is high. In additon, genera *Dinophysis* and *Prorocentrum* are important in the northmost of the AS (Turkoglu *et al*., 2004a; Turkoglu, 2007). For example, *Neoceratium extensum, N. furca var. eugrammum, N. furca var. furca, N. fusus var. fusus, N. fusus var. seta, N. fusus var. schuetti, N. tripos var. atlanticum, N.tripos var. pulchellum, N. setaceum,, Dinophysis acuminata*, *D. caudata*, *D. fortii*, *D. rotundata*, *D. rudgei*, *D. sacculus*, *Noctiluca scintillans*, *Prorocentrum compressum, P. micans*, *P. scutellum*, *Protoceratium aerolatum, Protoperidinium depressum*, *P. divergens*, *P. punctulatum*, *P. granii*, *P. steinii*, *Pyrophacus horologium* are the most important dinoflagellate species and some of them form algal blooms in some periods (Turkoglu *et al*., 2004a; Turkoglu, 2007). Species of the widespread genus *Neoceratium* may be mixotrophic (Smalley and Coats, 2002). They occupy selected depths (Tunin-Ley *et al*., 2007), and their distribution could change as a consequence of warming in the MS (Tunin-Ley *et al*., 2009). Finally, *Protoperidinium* spp. and several athecate dinoflagellates in the genera *Gymnodinium*, *Gyrodinium* and *Lessardia* are truly phagotrophic and they may constitute a main part of the microzooplankton (Sherr and Sherr, 2007), but their importance in the offshore MS has rarely been assessed (Margalef, 1985).

4. Phytoplankton Biomass and primary production in the Aegean Sea

The AS like in the EMS is rich in vertical mixture in all water column (Fig. 3). Therefore, all water column of the AS is rich in dissolved oxigen (DO) unlike the BS. On the other hand, except for Rhodos cyclonic and the NAS regions, due to the limited nutrient concentrations the first step in the food web (phytoplankton) is in lower levels particularly in surface waters of the AS (Yılmaz, 2002). In the region of Rodos cyclonic, nutriclin coincide with base of the light layer and localize in a shallow depth (50-100m). Therefore, in this cyclonic region primary production (chl-*a*) in the upper depths is relatively higher than the upper depths in anticyclonic regions of the AS (nutriclin layer: 200-700m) (Figure 3).

Except some coastal zones such as Güllük, Gerence and Izmir Bays, and some cyclonic regions such as Rhodos, light layer in the SAS is very poor in nutrient. It is known that due to the strong mixture observed and homegenization of the water column to 1000 m in the Rhodos cyclonic region in winter and early spring periods (March 1992, February 1993 and February 1995), it is easily realized the nutrient transport from the depth waters rich in nutrients to the lighty surface layer (Sur *et al.*, 1993). Therefore, the surface waters have been relatively high nutrient concentrations near to the depth waters (PO_4^{-3}-P: 0.18 μM, NO^-_3+NO^-_2-N 5.00 μM ve SiO_4 7.50 μM) (Yılmaz ve Tugrul, 1998) (Figure 3).

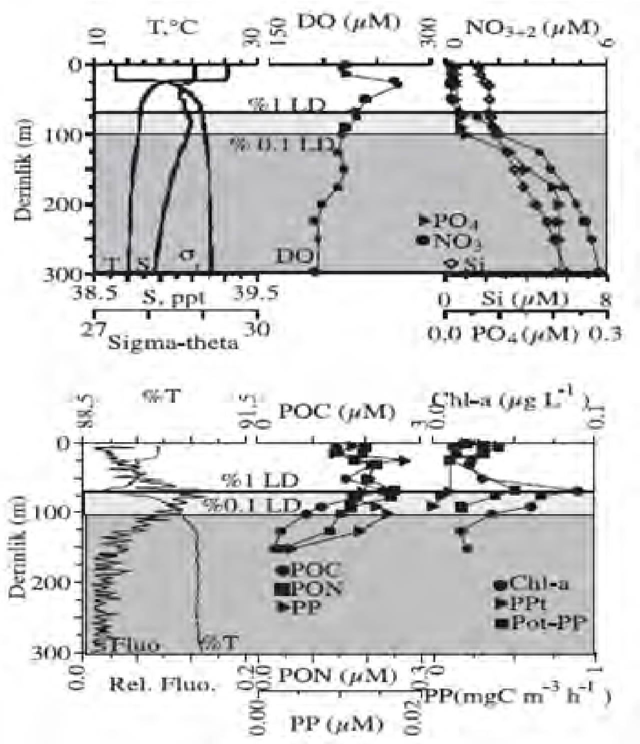

Figure 3. Vertical distribution of hydrographic, biogeochemical and production parameters in the Rhodos cyclonic region of the South Aegean Sea (35° 08' N and 28° 55' E) for the period of September 1997 (Yılmaz, 2002)

The most clearly impact of the previous measured physical and chemical characteristics is on the distribution of phytoplankton biomass as satellite-derived chl-a (Figure 4). High chl-a values (higher than 0.20 and even 0.50 µg L^{-1}) in the AS according to the Levantine Basin (LS) are displayed almost in all of the AS. Chl-a concentrations in the phytoplankton bloom areas including Northernmost region (NAS) and Chios basin and just under of the basin in late spring and early summer period (15 May-15 June 2015) are higher (higher than 0.50 chl-a µg L^{-1}) than any other (less than

0.50 chl-a µg L^{-1}). Reported phytoplankton blooms, though spatially limited, are also recorded in the Izmir Bay and the Saros Bay. Physical factors such as winds affecting winter mixing and coastal upwelling phenomenons, along with the presence of cyclonic structures such as Rhodos and Chios basins, are considered to be the most optimal physical factors allowing the building up of phytoplankton together with increase in nutrient. More high biomass locations are located near the coastlines, particularly in proximity to large river mouths such as Meriç and Büyük Menderes or extended continental shelves (Izmir Bay and NAS).

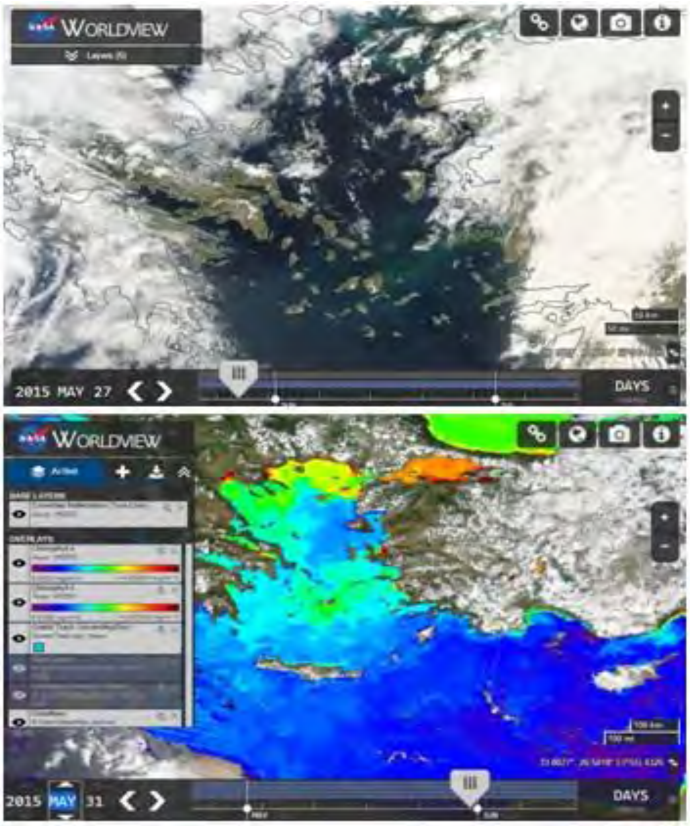

Figure 4. Spatial bloom and chlorophyll a distribution on satellite image, SeaWiFS in May 27, 2005 in the Aegean Sea (NASA, 2015)

Both satellite images and in situ chl-a values measured across the AS show a increase in oligotrophy of the system from the south to the north. The combined chl-a concentrations in almost all periods (Kucuksezgin *et al*., 1995; Dolan *et al*., 1999; Jönsson, 2000; Turkoglu *et al*., 2004; Turkoglu, 2007; Ignatiades *et al*., 2009) revealed a increase of a factor of about 10 from the east to the north (from interval of 0.05-0.10 to interval of 0.50-1.00 chl-a µg L^{-1}) (Figure 5). In addition to the south-north chl-a increase, a increasing phytoplankton bloom gradient from south to north is also evident from both satellite data and in situ phytoplankton cell density studies in both the southern and the northern basins (Koray, 1995; Turkoglu *et al*., 2004a; Turkoglu, 2007; Ignatiades, 1998, 2005; Balkis and Balci, 2009; Balkis, 2009; Aktan, 2011; Ciftci, 2011; Aglac and Balkis, 2014; Guresen and Aktan, 2014), with the exclusion of higher values along the Izmir Bay and some coastal zones (Figure 5).

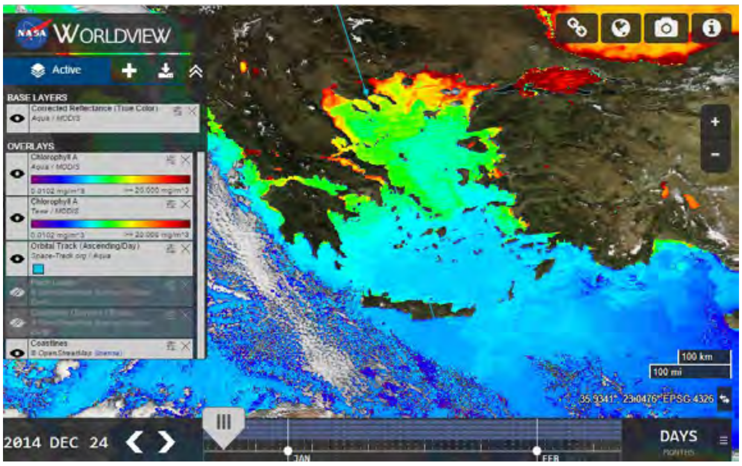

Figure 5. Increase in oligotrophy of the system from south to north according to chlorophyll a of the satellite image, SeaWiFS in early winter period (24 December 2005) in the Aegean Sea (NASA, 2015)

The relatively a few in situ studies on chl-a reported in different periods of the year in the AS confirm the patterns obtained from satellite image data, revealing seasonality in phytoplankton production processes. The chl-a maxima in the eastern basin of the MS except for the peak values of 1.34 μg L^{-1} in the frontal zone of the NAS Sea (Zervoudaki *et al.*, 2007) and 6.00 μg L^{-1} in the Saros Bay in spring period (Turkoglu *et al*., 2004a; Turkoglu, 2007) rarely exceed 0.50 μg L^{-1} (Kucuksezgin *et al*., 1995; Yacobi *et al*., 1995; Gotsis-Skretas *et al*., 1999), and the chl-a minima are as low as 0.005 μg L^{-1} (Kucuksezgin *et al*., 1995; Herut *et al*., 2000).

Most of the time, peak chl-a values (>2 μg L^{-1}) were found in subsurface waters. This was the case for for some cyclonic area of the North Levantine Sea such as Rhodos (Ediger and Yilmaz, 1996; Yilmaz, 2002). The highest value (16.0 μg L^{-1}) measured in the NAS was found in a 10 m thick subsurface layer in the NAS in the bloom periods of 2002-2003 (Turkoglu *et al*., 2004a; Turkoglu, 2007). In addition to these surface maxima a deep chl-a maxima (DCM), generally not exceeding 1.00 μg L^{-1}, is a permanent feature for the whole basin during the year, except for short period of late winter mixing and cyclonic mixing areas like in Rhodos (Ediger and Yilmaz, 1996; Yılmaz and Tugrul, 1998; Yılmaz, 2002), to 25-50 m in the NAS (Kucuksezgin *et al.*, 1995), down to 100 m in the SAS (Crete Basin, Fig. 1) (Kucuksezgin *et al*., 1995;

Christaki *et al.*, 1999, 2001). The increase in DCM depth from the northmost to the eastmost is probably related to lower productivity and so higher seawater transparency in the SAS like in Levantine Sea, but the depth levels of DCM may change considerably between cyclonic and anticyclonic areas (Ediger and Yilmaz, 1996).

Table 5. Primary production levels in the sub-basin of the Aegean Sea (NAS: North Aegean Sea; SAS: South Aegean Sea)

Sub-Basins	Time Period	mg C m^{-2} d^{-1}	g C m^{-2} y^{-1}	mg C m^{-2} h^{-1}	Data Origin	References
NAS	March 1997/98	81.36		96.7	in situ ^{14}C Surface	Ignatiades *et al.* (2002)
NAS	September 1999	232 (non-front) 326 (front)			in situ ^{14}C Surface	Zervoudaki *et al.* (2007)
NAS	April 2000	256 (non-front) 245 (front)			in situ ^{14} Surface C	Zervoudaki *et al.* (2007)
SAS	March 1997/98	38.88		38.9	in situ ^{14}C Surface	Ignatiades *et al.* (2002)
SAS	1994/95		59.0		in situ ^{14}C Surface	Psarra *et al.* (2000)
SAS	1994		24.79	5.66	in situ ^{14}C (0–50 m)	Ignatiades *et al.* (1998)
SAS	March 1994			6.56	in situ 14C (0–50 m)	Gotsis-Skretas *et al.* (1999)

Primary production levels according to in situ ^{14}C method (Table 5) show a increase from the South (SAS) to the north (NAS) in primary production like in all MS. For example, while the maxima of PP are close to 1.00 g C m^{-2} d^{-1} in the south-western basin and the minima ranged between 150 and 250 mg C m^{-2} d^{-1} at several stations of the LS (Moutin and Raimbault, 2002). Interestingly, estimates obtained in spring in other studies reflect the same spatial pattern and are within the same ranges as those shown by Moutin and Raimbault (2002). Measurements in the NEAS (Ignatiades *et al.*, 2002; Zervoudaki *et al.*, 2007) for except high primary production periods such as early winter, spring and late summer periods also match the low values in the LS reported by Moutin and Raimbault (2002).

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ZOOPLANKTON OF THE AEGEAN SEA

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1. Introduction

The Aegean Sea is topographically divided into two basins by approximately the 38° parallel, the north and south Aegean Sea. The hydrological and topographical conditions differ strongly between the two basins. The north Aegean Sea is characterized by an extreme continental shelf, favoring the proliferation of neritic and meroplanktonic forms, while in the south Aegean the continental shelf is limited except in the area around the Cyclades and the area has the characteristics of a pelagic zone. (Moraitou-Apostolopoulou, 1985). In Mediterranean, three different, and relatively isolated, subsystems can be identified (in terms of the structure of phytoplankton and zooplankton communities, along with their production and fertilization characteristics): the open sea, mainly influenced by enriching mechanisms which operate on a global scale, like the winter mixing and deep water formation intensity; coastal waters, which are more affected by wind-induced upwelling, rivers and land run-off; and embayments, in which the planktonic production is strongly influenced by urban effluents and stability conditions (UNEP/MAP, 1989).

Studies of the zooplanktonic organisms of the Aegean Sea have been initiated by several oceanographic cruises (Thor 1908-1910, Atlantis 1948, Calypso, 1955, Akademik Kovalevsky 1958, Akademik Vavilov 1960-1961). Kiortsis (1965) studied the plankton in northeast Aegean Sea quantitatively and qualitatively with its first detailed list. Having examined 151 plankton samples collected from 20 stations by Soviet expeditions between 1958-1961 Pavlova (1966) reported 120 species of copepod and calculated abundance and biomass of zooplankton as northern and southern Aegean Sea.

Kimor and Berdugo (1967) reported 25 species and genera of copepod from the 3 stations in southern Aegean Sea. Moraitou-Apostolopoulou (1973) studied the quantitative distribution of copepoda mainly from superficial samples across the Aegean Sea and reported related 114 species. Demir (1958, 1959) started early studies in Aegean Sea in Turkey on determination of copepoda fauna. In addition, the studies by Ergen (1967) in Izmir bay and by Gökalp (1972) in Edremit, Bodrum and Iskenderun bays were the pioneer for those on in zooplankton in Turkey. The studies have been increasingly continuing and yet prove less in number than those in other Mediterranean basins.

2. Qualitative Aspect

Copepods are the best studied group of mesozooplankton (200µm-2mm) in terms of their roles in abundance, biomass and the cycle of matter and energy in pelagic marine ecosystems. Considering the studies made so far, the table 1 presents number of copepod species established in eastern Mediterranean Sea.

Bakır *et al*., (2014) concluded that 108 copepod species have been determined in Turkish Aegean coasts.

Table 1. Number of copepoda species in different seas of eastern Mediterranean (Data from Siokou *et al*., 2014 and Razouls *et al*., 2005-2015).

Seas	Number of Species
Adriatic	285
Ionian and Sicilian-Libyan Area	240
Levantine	319
Aegean	202
Marmara	130

The zooplanktonic communities of Aegean Sea are clearly dominated by copepods except some coastal areas during summer and early autumn when cladocerans are dominant. They usually constitute the 70%-95% of the total number of zooplanktonic organisms (Moraitou-Apostolopoulou, 1985; Kovalev *et al*., 1999). Copepod fauna of Aegean Sea is generally Atlantic in origin. Indo-pacific species in origin; *Parvocalanus crassirostris* (Dahl F., 1894), *Calocalanus pavoninus* Farran, 1936, *Calanopia elliptica* (Dana, 1849), those in Mediterranean origin or first described in Mediterranean are; *Calocalanus adriaticus* Shmeleva, 1965, *C. elegans* Shmeleva, 1965, *C. gresei* Shmeleva, 1973, *C. neptunus* Shmeleva, 1965, *C. plumatus* Shmeleva, 1965, *Centropages ponticus* Karavaev, 1895, *Acartia (Hypoacartia) adriatica* Steuer, 1910, *Paracartia latisetosa* (Krichagin, 1873), *Labidocera brunescens* (Czerniavsky, 1868), *Ratania flava* Giesbrecht, 1893, *Ditrichocorycaeus brehmi* (Steuer, 1910), *Oncaea vodjanitskii* Shmeleva and Delalo, 1965. They are mainly composed of epi and epi-mesopelagic, neritic-oceanic and oceanic species. Because the Gibraltar strait is a sill as a physical barrier to Atlantic Ocean, bathypelagic species are hardly found there just as in the entire Mediterranean. The important copepod species are; a) Coastal and open waters of the North Aegean Sea: *Acartia (Acartiura) clausi* Giesbrecht, 1889 *Paracalanus parvus* (Claus, 1863), *Centropages typicus* Krøyer, 1849, *Temora stylifera* (Dana, 1849), *Clausocalanus arcuicornis* (Dana, 1849), *C. furcatus* (Brady, 1883), *C. paululus* Farran, 1926, *C. pergens* Farran, 1926, *Ctenocalanus vanus* Giesbrecht, 1888, *Oithona similis* Claus, 1866 b) Turkish coastal waters of middle Aegean Sea: *P. parvus* (Claus, 1863), *C. furcatus* (Brady, 1883), *C. typicus* Krøyer, 1849, *T.stylifera* (Dana, 1849), *A.(Acartiura) clausi* Giesbrecht, 1889, *Oithona plumifera* Baird, 1843, *O. similis*

Claus, 1866 c) Coastal and open waters of South Aegean Sea: *C. arcuicornis* (Dana, 1849), *C. furcatus* (Brady, 1883), *C. paululus* Farran, 1926, *O. plumifera* Baird, 1843, *O. similis* Claus, 1866, *Acartia (Acartia) negligens* Dana, 1849, *Calocalanus pavo* (Dana, 1852), *Haloptilus longicornis* (Claus, 1863), *Farranula rostrata* (Claus, 1863), *Agetus typicus* Krøyer, 1849, *Corycaeus* (*Onchocorycaeus giesbrechti)* (Dahl F., 1894), *Oncaea media* Giesbrecht, 1891, (Moraitou-Apostolopoulou, 1985; Pancucci-Papadopouou,1992; Tarkan, 2000; Aker, 2002; Siokou-Frangou, 2004). Following from data of abundance in variety of studies performed in autumn, dominant copepod genera are in figure 1. Species < 1 mm are observed to dominate the population. Neritic and coastal species such as *A. clausi* and *P. parvus* in neritic zone of northern Aegean Sea are more abundant than those in Southern Aegean region. Abundance of *P. parvus* decreases with replacement of *A. clausi* by *A. negligens* due to oceanic character of southern Aegean Sea, which is of high diversity in species. In general, *Clausocalanus spp.* and *Oithona spp*. there are most important species of copepod fauna there only with inclusion of large *C. typicus* and *T. stylifera* species during warm and cold periods in the fauna, respectively.

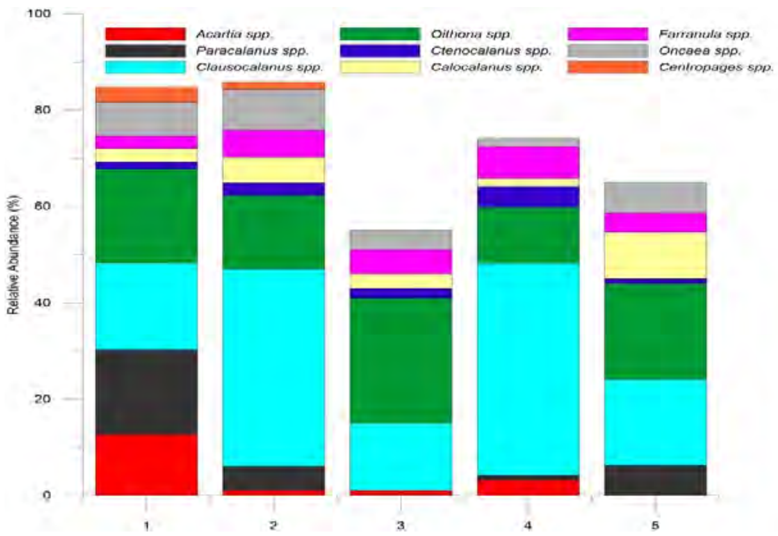

Figure 1. Relative abundance of dominant copepods. 1: north neritic, 2: north neritic-oceanic, 3: south neritic, 4: south oceanic, 5: across Aegean Sea oceanic. Data from: (Siokou *et al*., 1997; Isari *et al*., 2006; Zervoudaki *et al*., 2006; Sever, 2009; Mazzocchi *et al*., 2014).

Influences of physical and chemical factors such as temperature, salinity, turbidity, pollutants in littoral areas or bays are more significant than those in neritic and oceanic zones. Under those conditions, less tolerant species are eliminated (Gaudy, 1985). However, those having adjusted themselves to the circumstances increase quantitatively with a population of copepod rich in number and poor in species. For instance, *A. clausi* and *Oithona nana* in winter and spring and *Paracartia grani* and *Centropages kroyeri* during summer and autumn form almost entire population in the inner bay of Izmir (in this study).

Cladoceran occur predominantly in coastal waters of the oceans, often in swarms, and have been regarded mainly as neritic species (Della Croce and Venugopal, 1972). These are epiplanctonic animals, occurring predominantly in coastal waters may significantly contribute to mesozooplankton especially from early spring to late autumn (Christou *et al*., 1995). Of the approximately 600 species of so-called Cladocera only 7 species are marine (Onbe, 1999). Four species of cladoceran *Penilia avirostris* Dana, 1849, *Evadne spinifera* P.E.Müller, 1867, *Pseudevadne tergestina* (Claus, 1877) and *Podon intermedius* Lilljeborg, 1853 were independently reported by Pavlova (1966) and Moratiou-Apostolopoulou and Kiortsis (1974) from offshore of Aegean Sea. Gökalp (1972) reported *Evadne nordmanni* Lovén, 1836 and *Pleopis polyphaemoides* (Leuckart, 1859) in addition to those above. Six cladoceran species have thus far been known to exist offshore and coastal waters of Aegean Sea, of which *E. spinifera* is a thermophilic and dominant cladoceran species in Aegean Sea in summer and autumn. Another thermophilic species is *P. avirostris* as a subdominant species decreases in abundance from north to south and summer to winter. *P. intermedius* is psychrophilic species with highest abundance in winter (Moraitou-Apostolopoulou, 1974; Aker 2002). *E. nordmanni* is a coastal-oceanic cold water species and *P. polyphaemoides* a temperate coastal embayment and estuarine species with both distributing locally as compared to other species. *E. nordmanni* consists of 55% and 18% of the population in spring and winter, respectively. *P. polyphaemoides* consists of 1% and of the population in summer (Tarkan, 2000). Cladoceran population is almost composed of *P. polyphaemoides* in Izmir inner bay in all seasons but summer. *E. nordmanni* reaches to considerable abundance in Izmir outer bay in spring and *P. avirostris* as a dominant species reaches to highest abundance in summer (Aker and Özel, 2006).

Appendicularians is a particularly important compartment of mesozooplankton in that it ranges from 3% to 21 in neritic epiplankton (Pancucci-Papadopoulou *et al*., 1992; Aker 2002; Isari *et al*., 2006; Zervoudaki *et al*., 2014). 29 of 34 species of Mediterranean appendicularia was reported from Saranikos Gulf (Fenaux, 1972 and Furnestin, 1979). Appendicularians are considered a group without sufficient studies on their species-level distribution and abundance. Only their 7 species were reported from Turkish Aegean Sea: *Oikopleura (Vexillaria) dioica* Fol, 1872, *Oikopleura (Coecaria) fusiformis* Fol, 1872 (Ergen, 1967), *Fritillaria pellucida* (Busch, 1851), *Tectillaria fertilis* (Lohmann, 1896) (Gökalp, 1972), *Oikopleura (Coecaria) longicauda* (Vogt, 1854), *Fritillaria borealis* Lohmann, 1896 (Mavili, 1987). Tarkan (2000) reported *Stegosoma magnum* (Langerhans, 1880) of northern coastal Aegean Sea, adding that *O. dioica* is a dominant appendicularian species. Number of species in appendicularians is found less in epiplancton but increases in depth. *Oikopleura* spp. is coastal and littoral while *Fritillaria* spp. neritic and oceanic in distribution.

At the secondary consumer level, chaetognats comprise the most important zooplankton group in the Mediterranean Sea (Scotto di Carlo and Ianora, 1983). They are common, comparatively long lived and have proved particularly useful as indicator species to identify the origins or source of particular water masses (Ghirardelli, 2010). Kiortsis (1965) reported that three species such as *Flaccisagitta enflata* (Grassi, 1881), *Mesosagitta minima* (Grassi, 1881) and *Serratosagitta serratodentata* (Krohn, 1853) are of moderate. Ghirardelli and Rottini (1979) reported 10 species and their abundances: *S. serratodentata* (Krohn, 1853), *Pseudosagitta lyra* (Krohn, 1853), *Flaccisagitta hexaptera* (d'Orbigny, 1836), *Decipisagitta decipiens* (Fowler, 1905), *Parasagitta setosa* (Müller, 1847), *Sagitta bipunctata* Quoy & Gaimard, 1828, *Krohnitta subtilis* (Grassi, 1881) and *Eukrohnia hamata (Möbius, 1875). F. enflata* (Grassi, 1881) and *M. minima* (Grassi, 1881) consist of 44% of chaetognath population. The studies made in southern Aegean region later determined all other species except *E. hamata* and *F. enflata*, *M. minima*, *S. bipunctata, S. serratodentata* and *P. setosa* being most abundant chaetognath species in Aegean Sea (Kehayias, 1997 and Kehayias *et al*., 1999). Chaetognaths are an another taxon examined in group level in mesozooplankton studies. Only 3 chaetognath species were reported from our Aegean coasts. Ergen (1967) reported species of *Flaccisagitta enflata* (Grassi, 1881), *Serratosagitta serratodentata* (Krohn, 1853) from Izmir bay. *Parasagitta setosa* (Müller, 1847) and *F. enflata* from northern Aegean Sea coastal area consist of the entire chaetognath fauna in the study area (Tarkan, 2000). Highest percentage of total mesozooplankton in middle Aegean Sea neritic zone was observed in winter with a mean of 1,82% (Aker, 2002). Unlike cladocerans and appendicularians, chaetognats are in abundance increasing from surface to deep water (Mazzocchi *et al*., 1997). Their epipelagic populations are usually made up of immature specimens, which makes it difficult to identify species in neritic and coastal studies.

Hydromedusae, siphonophorans, thaliaceans (salps and doliolids) and ctenophorans are included in meso and macrozooplankton. Sycphozoans are large and truly jellyfish species and called gelatinous zooplankton together with all the above-said. *Rhizostoma pulmo* (Macri, 1778) and *Cotylorhiza tuberculata* (Macri, 1778) were the first to be reported to be Scyphozoan species from Turkish Aegean coasts. The first jelly fish bloom was reported together with *Drymonema dalmatinum* Haeckel, 1880 in Izmir Bay. A total of 10 species were reported to be distributed in Izmir Bay and Aegean Sea as *Aurelia aurita* (Linnaeus, 1758) *Chrysaora hysoscella* (Linnaeus, 1767) *Pelagia noctiluca* (Forsskål, 1775) *Nausithoe punctata* Kölliker, 1853, *Cassiopea andromeda* (Forsskål, 1775), *Phyllorhiza punctata* Lendenfeld, 1884 and *Carybdea marsupialis* (Linnaeus, 1758) as a suspicious (Çınar *et. al*., 2014). There are a few studies on Hydromedusae including *Rhopalonema velatum* Gegenbaur, 1857, *Olindias* *phosphorica* (Delle Chiaje, 1841), *Aglaura hemistoma* Péron & Lesueur, 1810, *Geryonia proboscidalis* (Forsskål, 1775) reported from Aegean Sea (Çınar *et al*., 2014). Siphonophorans are colonial organisms with complex life cycles and grouped in zooplankton samplings often in colony individuals such as nectophore, pneumotophore and bracte. Forbes 1844, Ergen (1967), Gökalp (1972) and Tarkan (2000) reported *Lensia conoidea* (Keferstein & Ehlers, 1860), *Abylopsis tetragona* (Otto, 1823), *Eudoxoides spiralis* (Bigelow, 1911), *Lensia subtiloides* (Lens & Van Riemsdijk, 1908) and *Lensia conoidea* (Keferstein & Ehlers, 1860) from Aegean Sea, Izmir Bay, Bodrum bay, and northern Aegean Sea, respectively. Moreover, a total of 22 species of siphonophoran distribute across Aegean Sea. *Bassia bassensis* is the commonest followed by *E. spiralis* (Moraitou-Apostopoulo, 1985). Thaliaceans are filter-feeding organisms and Gökalp (1972) was the first to report *Thalia democratica* (Forskål, 1775) from Aegean Sea coasts. *T. democratica* is the dominant form among the salps in the Aegean Sea (Moraitou-Apostolopoulou, 1985). Tarkan (2000) reported *Doliolina muelleri* (Krohn, 1852) and *Doliolum denticulatum* Quoy & Gaimard, 1834 and their abundances. Four ctenophoran species were reported of *Bolinopsis vitrea* (L. Agassiz, 1860), *Pleurobrachia rhodopis* Chun, 1879 (Ergen, 1967), *Mnemiopsis leidyi* A. Agassiz, 1865 and *Bolinopsis infundibulum* (O.F. Müller, 1776) from Izmir Bay in our Aegean Sea coasts (Çınar *et al*., 2014).

Pteropods, an informal name for planktonic molluscs of the orders Thecosomata (shelled) and Gymnosomata (naked), are common in all marine environments from the poles to the equator, and from the surface to bathypelagic depths. Pteropods are typically open-ocean organisms, and although many may be encountered in neritic waters, there are no real coastal species (Spoel and Dadon, 1999). Such group organisms are rarely encountered due to their distributional properties. *Creseis acicula* Rang, 1828, *Hyalocylis striata* (Rang, 1828), *Heliconoides inflatus* (d'Orbigny, 1834), *Limacina trochiformis* (d'Orbigny, 1836), *Clio pyramidata* Linnaeus, 1767, *Cavolinia gibbosa* (d'Orbigny, 1834*), C. inflexa* (Lesueur, 1813), *Cymbulia peronii* de Blainville, 1818 were reported to be 8 species (Öztürk *et al*., 2014), of which is *C. acicula* most abundantly found. In Aegean Sea, 13 species of pteropoda are known (Furnestin, 1979). Heteropods are among seldom groups such as Pteropods. *Firoloida desmarestia* Lesueur, 1817, *Pterotrachea hippocampus* Philippi, 1836, *Atlanta peronii* Lesueur, 1817 were reported as 3 species (Öztürk *et al*., 2014).

Pelagic amphipods are large and rarely found specimens which could be sampled during nocturnal towing using standard zooplankton nets. Katağan and Özel (1987) reported 17 species from Aegean Sea namely, *Hyperia galba* (Montagu, 1815), *Lestrigonus schizogeneios* (Stebbing, 1888), *L. latissimus* (Bovallius, 1889), *Phrosina semilunata* Risso, 1882, *Anchylomera blossevillei* Milne-Edwards, 1830, *Primno macropa* Guérin-Méneville, 1836, *Eupronoe minuta* Claus, 1879, *Lycaea pachypoda* (Claus, 1879), *L. pulex* Marion, 1874, *Platyscelus ovoides* (Risso, 1816), *P. serratulus*

Stebbing, 1888, *Tetrathyrus forcipatus* Claus, 1879, *Phronima atlantica* Guérin-Méneville, 1836, *Lycaeopsis themistoides* Claus, 1879, *Simorhynchotus antennarius* (Claus, 1871), *Parascelus typhoides* Claus, 1879, *Amphithyrus bispinosus* Claus, 1879. Aydın and Özel (2007) reported species of *Hyperioides longipes* Chevreux, 1900, *Leptocotis tenuirostris* (Claus, 1871), *Paraphronima crassipes* Claus, 1879, *Phronima stebbingi* Vosseler, 1901, *Themisto gaudichaudii* Guérin, 1825. With the recent addition of those by Aydın (2012), number of species has amounted to 27 known to exist across Turkish Aegean coasts; *Parathemisto oblivia* (Kroyer), *Lestrigonus curcipes* (Bovallius, 1889*), L. macrophytalmus* (Vosseler, 1901), *Primno latreillei* (Stebbin, 1888*), Paralycae gracilis* (Claus, 1879).

Planktonic ostracods are crustaceans with usually oceanic distributions which are seldom found during standard plankton samplings. Three species were reported from Izmir Bay; *Porroecia porrecta* (Claus, 1890), *Archiconchoecia striata* G.W. Müller, 1894, *Mikroconchoecia curta* (Lubbock, 1860) (Erkmen and Özel, 2007). Seven species were from Aegean Sea (Moraitou-Apostolopoulou, 1981).

Meroplankton amount to significant abundance in coastal areas and increases in diversity across neritic zones. Eleven meroplanktonic groups were established in middle Aegean Sea, the most important of which are bivalvia and gastropoda veliger larvae. Highest abundance of meroplankton were seen in summer (Aker, 2002).

3. Quantitative Aspect

Eastern Mediterranean has long being considered as an oligotrophic area. It has repeatedly been stated that the Mediterranean is characterized by low levels of nutrients and consequently of productivity and that is poverty increases from west to east (Moraitou-Apostolopoulou, 1985). According to Kovalev *et al*., (1999) there is a significant reduction in biomass of macrozooplankton from the west to the east in the Mediterranean Sea. Table 2 has been prepared using data of abundance and biomass.

Northern Aegean Sea under the influence of Black Sea surface water and river inflows shows higher values abundance and biomass than southern Aegean Sea. Spring shows lower abundance and higher biomass in value than autumn. The most productive is Adriatic in abundance and biomass whereas Levantine is the poorest in biomass if not in abundance in Mediterranean Sea, the reason for which is that zooplankton fauna is composed of less individuals and the region is of oligotrophic character. Only according to mean abundance and biomass values in summer is Aegean Sea similar to Ionian Sea.

Table 2. Mesozooplankton abundance (ind. m^{-3}) and biomass (mg dry weight m^{-3}, or wet weight, *italics*) values collected by 200-250 µm mesh nets in several areas of the eastern Mediterranean Sea.

Area	Season	Column	Abundance (ind. m^{-3})	Biomass (mg. m^{-3})	Author
Adriatic	Summer average 1958-82	0-200 m	1,724	*56*	Kovalev *et al.*, 1999
Ionian			1,041	*33*	
Levantine			1,438	*18*	
Aegean			1,032	*23*	
North Aegean	Autumn 58	0-100 m	1,473	*47*	
Middle Aegean	Sep-Oct 80	0-100 m	867	*22*	
North Aegean	Apr 08	0-80 m	771	16.2	Hannides *et al.*,2015
	Sep 08		912	4.3	
	Mar 97	0-100 m	2,708	37.4	Siokou *et al.*,2013
	Sep 97	0-100 m	3,488	17.6	
South Aegean	Mar 97	0-100 m	799	11.4	
	Sep 97	0-100 m	1,409	10.4	

4. Conclusion

The majority of zooplankton species are small-size atlanto-mediterrenaean individuals known to be in western Mediterranean. The most significant component of the zooplankton communities is the copepods (mostly calanoids). Species Aegean indo-pacific in origin are also included in the fauna concerned in southern Aegean Sea, where boreal forms do not prevail unlike northern Aegean Sea. Neritic regional fauna includes members of familias Paracalanidae, Centropagidae, Temoridae, Acartiidae and Oithonidae. Most species of Calanidae, Clausocalanidae, Centropagidae, Oithonidae, Oncaeidae and Corycaeidae distribute together in neritic and oceanic regions. However, individuals of Aetidae, Scolecithricidae, Heterorhabdidae, Eucalanidae, Augaptilidae and Spinocalanidae form mesopelagic deep water fauna. Eutrophic littoral regions exhibit a zooplankton community rich in abundance and poor in number of species. The deeper, the lower abundance and biomass are in copepods. Cladocerans is second to copepods in numerical abundance. From summer until autumn, they are more numerous than copepods. Appendicularians and chaetognaths are the most important secondary constituents of the holoplankton.

There are few studies on zooplankton and population structure in Aegean Sea. Although copepoda and cladocera species are known relatively better, other groups have been neglected. For example, there is almost no data of planktonic groups such as foraminifera, acantharia, radiolaria, polychaeta, euphausiacea and pelagic decapoda. The study has tried to evaluate structure of zooplankton community in Aegean Sea using the present literature. We do expect that studies on Aegean Sea zooplankton could be brought to the level of research into Marmara Sea and Turkish coast of, Black Sea and Levantine Sea.

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SPONGES OF THE AEGEAN SEA

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1. Introduction

Sponges were used for different aims from antiquity mostly for cosmetics due to their soft and high water containing capacity spongin skeletons. Aegean Sea is one of the main basins for sponge fisheries. Sponges are one of the primer export items in the 19th century from Ottoman Empire. And sponge always an important issue especially in the Aegean coasts due to its trade and Bodrum considered as most imported places of Turkish Sponge industry. Sponge fisheries mostly were made by Greek fisherman during the Ottoman period (Yürekli, 2011). At the first period of the Turkish republic sponges were also one of the important export item (Yürekli, 2012).

The sponges have many other area of usage at the present such as medical or industrial area. Therefore, sponge studies have highly importance.

History of sponge fisheries and studies:

At the second half of 19th century sponge trades was one of the main items and also affected by the technical developments on the Sponge fishing and processing methods (Yürekli, 2011). Somehow, the sponges and its trade always important and especially Bodrum considered as most imported center of Turkish Sponge industry during the Ottoman period and first period of Turkish Republic (Yürekli, 2011 and 2012). Mainly four methods were used for the sponge fishing during the first period. These are “Tridend” a kind of spear; “Algarna or Kankava” a kind of deep trawls; “Apnist” ABC diving and “Scafander” old style diving suit (Yürekli, 2011). According to Çoruh (2009) the sponge fisheries was start in beginning of 1840’s in western side of Anatolian coast, together with Cyprus, Aegean Islands (Crete, Sporades, Simi, Khios, Lesvos, Samos and, Kalymnos) and the coasts of North Africa (Syria, Egypt and Libya). But, the main places of sponge fisheries were in shallow waters of Anatolian coast, together with Crete and Rhodes islands.

Figure 1. Old style diving suit "Scafander" (after Topaloğlu, 2012)

After the Ottoman period mostly the aquaculture and of sponge were studied in Turkish waters (Gökalp, 1974; Dalkılıç, 1982 and Ergüven, *et al*., 1988). The sponge production and exports of Turkey was continued due to favorable habitat conditions for 1961 (Canyiğit, 1962a). The production were reported as 15 tonnes follow by Marmaris 7-7,5 tonnes, Gökçeada and Bozcaada with 5 tonnes each (Canyiğit, 1962b). Topaloğlu (2012) reported that, the sponge industry in Turkey based on the distribution according to different locations and the sponge export of the country between the years of 1951-1962. The correlation between sponge and sponge fishing boats registered in Bodrum port and sponge production with export. The most important buyer of Turkish sponges was Greece based on Arısoy (1971).

Turkish sponge were popular in world market Turkey's sponge export plunged from 100 tons in 1910 to 13 tons in 1980. The reasons for this were given as technical insufficiency, negative trends in ecological conditions and unsuitable working conditions of sponge divers (Topaloğlu, 2012).

Figure 2. *Spongia officinalis* and a sponge seller (small UW photo by H. Yılmaz).

The epidemic sponge disease was appeared in 1986 in Turkish waters and Sponge populations especially economical sponge species affected negatively (Atahan *et al*. 1989). The sponge fishing is prohibited in the Turkish waters according to the regulation aimed for protect sponge stocks. Very limited numbers of the sponge dealer are importing (mostly from Greece) and selling sponge in the market (Topaloğlu 2012).

3.Actual Status of Sponge Studies:

According to Topaloğlu & Evcen (2014) sponges are one of the important groups of the biodiversity (12,4 % of total species number) in the Mediterranean based on the Coll *et al*. (2010). Zoogeographical distribution of the sponges was studied by Peres and Picard (1958), Pansini and Longo (2003), and Voultsiadou (2009) in the Mediterranean Sea and the sea divided four zones. Voultsiadou, (2005) published a check list for Sponge diversity in the Aegean Sea and the first records of sponges in the Aegean Sea given by Homer and Aristotle according to the author. He also reported 200 sponges species based on 48 publications by various authors in the group of taxonomic, faunistic, ecological and general faunistic and ecological studies.

The oldest study on sponges for Turkish Coast dated back to by Colombo (1885). He reported 5 sponge species from the Çanakkale Strait. Devedjian (1926) were reported general information on the sponge species of Turkey. Some information on sponge culture and economic values was given by Dalkılıç (1982) and Gökalp (1974). Sarıtaş (1972, 1973 and 1974) reported totally 50 species from İzmir Bay in a series studies. Yazıcı (1978) was reported 15 species around Gökçeada Island. A few number of sponge species were reported in general studies in the Aegean Sea (Geldiay and Kocataş, 1972; Kocataş, 1978; Ergüven *et al*., 1988; Katağan *et al*., 1991; Ergen *et al*.,1994; Çınar and Ergen, 1998; Koçak *et al*., 1999; Topaloğlu, 2001; Çınar *et al*., 2002 Gözcelioğlu *et al*., 2011)

The studies on bioactive compounds of the sponges have importance recently. The Marine natural products on the *Agelas oroides* from Gökçeada Island were studied and new antibiotic materials found aganist to *Plasmodium falciparum, Mycobacterium tuberculosis* and *Escherichia coli* (Tasdemir *et al*, 2007). Altuğ *et al*. (2012) were studied on potential anti-bacterial activity of marine sponge extracts from Gökçeada Island.

The latest faunistic studies on the Aegean Sea sponges were reported by a few numbers of authors. Kefalas and Castritsi- Catharios (2012) was reported a new species, *Topsentia vaceleti* n. sp., from 70m depth, on a coralligenous bed of the Aegean Sea.
Castritsi- Catharios *et al.* (2011) were studied on distribution and biometry of commercial sponges in coastal areas of the central and southeastern Aegean Sea. The author was investigated to estimate the recovery progress of the sponge disease. Beside this, sponge species special habitats such as caves were investigated recently. Manconi *et al.* (2013) studies 105 marine caves in all Mediterranean Sea and 14 of them from Greek side and islands of Aegean Sea. 40 sponge species were reported in the study that including 14 endemic species. Interaction of the sponge species with other marine organisms were also studies by various author Sponge inhabiting on the other organism such as Posidonia was studied (Sarıtaş, 1973). Sponges plays important role as habitat in the marine ecosystem. Çınar and Ergen (1998) were studies Polychaetes associated with *Sarcotragas muscarum* Schmidt, 1864 and 89 polycahete species were reported from cavities and surfaces of the sponge.

Totally 82 sponge species were reported in the Turkish Coast of Aegean Sea by Topaloğlu and Evcen (2014). Nine sponge species were reported from North Aegean Sea by Gözcelioğlu *et al*., (2015). Eleven bioeroding sponge species in Ildırı Bay belonging to Clionidae, Thoosidae, Phloeodictyidae and Chondrillidae families were reported. Five of these species were new record for the eastern Mediterranean fauna and six species for the marine fauna of the eastern part of the Turkish coast of Aegean Sea (Evcen and Çınar, 2015).

As a result Totally 142 Sponge species were reported from Turkish coastal waters and 95 of these from Turkish coasts of Aegean Sea (Table 1). Studies in the special habitat like marine caves are very limited especially in Turkish side of the Aegean Sea. The number of the sponge species will be increase with the new research on marine caves and deep waters. Therefore more researches are necessary for to find out the actual situation of the Aegean Sea sponge populations.

Table 1. Check list of sponge species from the coast of Turkey. AS: Aegean Sea; DR: Depth range (I: 0-10 m; II: 11-50 m; III: 51-100 m; IV: 101-200 m; V: 201-400 m; VI: 401-600 m; VII: >600 m). (revised from: Topaloğlu and Evcen, 2014)

Group/Species	AS*	DR
Phylum: PORIFERA		
Classis: CALCAREA		
Family: Sycattidae		
Sycon raphanus Schmidt, 1862	7,8,9,10,12	I-III
Family: Leucosoleniidae		
Leucandra aspera (Schmidt, 1862)	6,7,8	I-III
Family: Clathrinidae		II
Clathrina reticulum (Schmidt, 1862)	6	II
Classis: HOMOSCLEROMORPHA		
Classis: DEMOSPONGIA		
Family: Tethyidae		
Tethya aurantium (Pallas, 1766)	1,2,3,5,7,8,10	I-II
Family: Clionaidae		
Cliona celata Grant, 1826	13,17	I-III
Cliona vermifera Hancock, 1867	1	I
Cliona viridis (Schmidt, 1862)	1,3,7,17	I-II
Cliona schmidti (Ridley, 1881)	1,3	I
Cliona janitrix Topsent, 1932	17	
Cliothosa hancocki (Topsent, 1888)	1,3	I
Dotona pulchella mediterranea Rosell and Uriz, 2002	17	
Volzia albicans (Volz, 1939)	17	
Family Spirastrellidae		
Spirastrella cunctatrix Schmidt, 1868	17	
Family: Suberitidae		
Aaptos aaptos (Schmidt, 1864)	3	I-III
Protosuberites denhartogi Van Soest and de Kluijver, 2003	2,3	I-II
Rhizaxinella elongata (Ridley and Dendy, 1886)	16	I
Rhizaxinella pyrifera (Delle Chiaje, 1828)	8	I
Suberites domuncula (Olivi, 1792)	3,5,7,8,13	I-III
Suberites massa Nardo, 1847	9	I

Terpios gelatinosa (Bowerbank, 1866)	16	I
Family: Placospongiidae		
Placospongia decorticans (Hanitsch, 1895)	1,3	I
Family: Timeidae		
Timea fasciata Topsent, 1934	3	I
Timea mixta (Topsent, 1896)	2	
Timea stellata (Bowerbank, 1866)	2,3,6	I
Family: Chalinidae		
Haliclona (*Gellius*) *dubia* (Babic, 1922)	2,3	I-II
Haliclona (*Gellius*) *fibulata* (Schmidt, 1862)	2,3	I
Haliclona (*Haliclona*) *simulans* (Johnston, 1842)	7	II
Haliclona (*Reniera*) *cinerea* (Grant, 1826)	8	I
Haliclona (*Reniera*) *cratera* (Schmidt, 1862)	8	I
Haliclona (Rhizoniera) sarai (Pulitzer-Finali, 1969)	15	II
Halichondria (Halichondria) contorta (Sarà, 1961)	15	II
Family: Callyspongiidae		
Siphonochalina coriacea Schmidt, 1868	8	I-II
Family: Petrosiidae		
Petrosia (*Petrosia*) *ficiformis* (Poiret, 1789)	2,3,8,13	I-III
Family Phloeodictyidae		
Siphonodictyon infestum (Johnson, 1889)	17	
Family: Dictyonellidae		
Acanthella acuta Schmidt, 1862	15	II
Family: Axinellidae		
Axinella cannabina (Esper, 1794)	7,8,13	I-III
Axinella damicornis (Esper,1794)	3,13	I-III
Axinella polypoides Schmidt, 1862	7,8,13	I-III
Axinella pumila Babic, 1922	3	II
Axinella verrucosa (Esper, 1794)	3,7,8,15	II
Family: Halichondriidae		
Axinyssa digitata (Cabioch, 1968)	16	I
Axinyssa aurantiaca (Schmidt, 1864)	15	II
Hymeniacidon perlevis (Montagu, 1818)	6	II
Halichondria (*Halichondria*) *panicea* (Pallas, 1766)	4, 8	I

Family: Ancorinidae		
Ancorina cerebrum (Schmidt, 1862)	3	III
Dercitus (*Stoeba*) *plicatus* (Schmidt, 1868)	3	I
Holoxea furtiva Topsent, 1892	1,3	I
Stelletta dorsigera Schmidt, 1864	3,6	II
Stelletta grubii (Schmidt, 1862)	3	I
Stelletta stellata Topsent, 1893	3	I-II
Stryphnus ponderosus (Bowerbank, 1866)	3	III
Family: Pachastrellidae		
Thenea muricata (Bowerbank, 1858)	3	III-VII
Family: Geodiidae		
Erylus discophorus (Schmidt, 1862)	1,2,3	I
Geodia cydonium (Jameson, 1811)	1,2,3,7,8	I-III
Geodia conchilega Schmidt, 1862	2,3	I
Penares euastrum (Schmidt, 1868)	3	III
Penares helleri (Schmidt, 1864)	8	I
Family: Calthropellidae		
Calthropella stelligera (Schmidt, 1868)	3	I
Family: Thoosidae		
Alectona millari Carter, 1879	1,17	I
Delectona madreporica Bavestrello, Calcinai, Cerrano, Sarà, 1997	17	
Thoosa mollis Volz, 1939	17	
Family: Mycalidae		
Mycale (*Aegogropila*) *contareni* (Martens, 1824)	2,3	I-III
Mycale (*Aegogropila*) *rotalis* (Bowerbank, 1874)	2,3	I-III
Mycale (*Aegogropila*) *tunicata* (Schmidt, 1862)	2,3	I-III
Mycale (*Carmia*) *macilenta* (Bowerbank, 1866)	2,3	I-III
Mycale (*Mycale*) *massa* (Schmidt, 1862)	1,3	I-III
Family: Tetillidae		
Craniella cranium (Müller, 1776)	3	III
Family: Samidae		
Samus anonymus Gray, 1867	3	I
Family: Plakinidae		
Plakina monolopha Schulze 1880	3	I

Family: Agelasidae		
Agelas oroides (Schmidt, 1862)	3,8,13	I-III
Family: Dictyonellidae		
Dictyonella incisa (Schmidt, 1880)	15	II
Family: Myxillidae		
Myxilla (*Myxilla*) *prouhoi* (Topsent, 1892)	3	II-III
Myxilla (*Myxilla*) *rosacea* (Lieberkühn, 1859)	1,2,3,8	I-III
Family: Coelosphaeridae		
Lissodendoryx (*Anomodoryx*) *cavernosa* (Topsent, 1892)	2	I
Family: Crambeidae		
Crambe crambe (Schmidt, 1862)	1,3	I-II
Family: Crellidae		
Crella (Pytheas) fusifera Sarà, 1969	3	II
Family: Hymedesmiidae		
Hemimycale columella (Bowerbank, 1874)	8	I
Hymedesmia (Hymedesmia) anatoliensis Gözecelioglu, Soest, Alvarez & Konuklugil 2015	15	II
Family: Acarnidae		
Acarnus tortilis Topsent, 1892	2,3	I-II
Family: Tedaniidae		
Tedania (*Tedania*) *anhelans* (Lieberkühn, 1859)	2,3,7,8	I-II
Family: Raspailiidae		
Raspailia (*Raspailia*) *viminalis* Schmidt, 1862	3,5,8	II
Family: Microcionidae		
Clathria (*Clathria*) *coralloides* (Olivi, 1792)	8	II
Clathria (*Microciona*) *strepsitoxa* (Hope, 1889)	13	I-III
Clathria (*Thalysias*) *jolicoeuri* (Topsent, 1892)	2,6	II
Family: Irciniidae		
Ircinia variabilis (Schmidt, 1862)	8	I-II
Sarcotragus foetidus Schmidt, 1862	6,8,9,11,14	I-II
Family: Dysideidae		
Dysidea avara (Schmidt, 1862)	7,8	I-III
Dysidea fragilis (Montagu, 1818)	8	I-III
Dysidea tupha (Martens, 1824)	8	I

Family: Thorectidae		
Scalarispongia scalaris (Schmidt, 1862)	8	I-II
Family: Spongiidae		
Hippospongia communis (Lamarck, 1814)	7,8	II-III
Spongia (Spongia) officinalis Linnaeus, 1759	7,8,9	I-III
Spongia (Spongia) virgultosa (Schmidt, 1868)	8	I
Family: Aplysinidae		
Aplysina aerophoba Nardo, 1843	5,8,9,13	I-III
Family: Chondrillidae		
Chondrosia reniformis Nardo, 1847	8,9,13,17	I

*Acc. to; 1: Saritas (1972), 2: Saritas (1973), 3: Saritas (1974), 4: Pınar (1974), 5: Geldiay and Kocatas (1972), 6: Kocatas (1978), 7: Yazici (1978), 8: Erguven (1988), 9: Ergen *et al*. (1994), 10: Ergen and Cinar (1994), 11: Cinar and Ergen(1998), 12: Kocak *et al*. (1999), 13: Topaloglu (2001), 14: Cinar *et al*. (2002), 15: Gözecelioğlu *et al*. (2015), 16: Topaloğlu and Evcen (2014), 17: Evcen and Çınar (2015).

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ANTHOZOANS OF THE AEGEAN SEA

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1. Introduction

Anthozoans, a group of 164 species in the Mediterranean Sea (Coll *et al.* 2010), are amongst the most conspicuous and attractive marine organisms. In the Aegean Sea, 90 anthozoan species were reported, with 28 octocorals and 62 hexacorals (Vafidis 2010). Despite this high number for the Aegean Sea, only 41 species were reported along Turkish Aegean coasts, with 34 hexacorals and 7 octocorals (see Çınar *et al*. 2014 for a check-list). The main reason for this reduced number of species is probably the insufficient research effort on this class. Only few studies focused particularly on anthozoans (e.g. Coşar 1974, Yurtsever 2002) and other sporadic reports were part of more general studies (e.g. Geldiay and Kocataş, 1972) or were listed in guide-books (e.g. Öztürk 2004; Gökalp 2011). As a matter of fact, a recent study with only two sampling locations in the Aegean Sea reported 5 new records for Turkish Aegean coasts (Çınar *et al*. 2014), which demonstrates the need for specific studies on anthozoans. Research efforts should particularly focus on offshore and deep sea species and small sized unobtrusive species at the coasts. In spite of a low number of taxonomic and ecological studies on anthozoans, two arborescent species were cited as threatened by set nets and sport divers in a study [*Eunicella singularis* (Esper, 1791) as vulnerable and *Savalia savaglia* (Bertoloni, 1819) as endangered] (Öztürk & Öztürk 2000).

Gorgonians in Coralligenous Communities of the Aegean Sea

Gorgonians are key components of Mediterranean benthic ecosystems (Gili & Coma 1998), particularly of coralligenous communities (Ballesteros 2006) which are considered as the second most important 'hot spot' of species diversity in the Mediterranean, after the *Posidonia oceanica* meadows (Boudouresque 2004). They are habitat former species, providing three dimension structural complexity and harbouring high levels of biodiversity (Gili & Coma 1998). Gorgonians are characterized by long lives, slow growth and low recruitment rates, therefore they are highly vulnerable vis-à-vis natural/anthropogenic disturbances (Linares *et al.,* 2005).

In the Aegean Sea, 12 gorgonians were reported (Vafidis 2010) but only 3 of them were so far found along Turkish coasts (Table 1) due probably to insufficient research effort, particularly on deep sea and offshore habitats. Actually, gorgonians are generally found at depths greater than 30 m in the Aegean Sea (Salomidi *et al*. 2009; Sini *et al*.

2015) and this deeper distribution than that in the western Mediterranean Sea might have limited their studies along Turkish Aegean coasts.

Despite there are only few scientific studies on gorgonians in the Turkish Aegean Sea, there are a number of “hot-spot” sites known to all divers. The most renowned ones among these sites are found in Ayvalık region where relatively “dense” populations of *Paramuricea clavata* (Risso, 1826) and *Eunicella cavolini* (Koch, 1887) are present (Yurtsever 2002; Figure 1A). A recent study on the genetic structuring in the red gorgonian *P. clavata* over the Mediterranean Basin revealed a reduced genetic diversity of a population in this region (Mokhtar-Jamaï *et al*. 2011). Similarly, low levels of allelic richness and heterozygosity were reported for an *E. cavolini* population in Ayvalık region (Masmoudi *et al.* 2013).

Another region with relatively dense populations of gorgonians is the bay of Saros. This is a unique region along Turkish coasts, where *E. singularis* colonies are relatively abundant, especially at shallow depths (Topçu pers. obs.). Both *E. cavolini* and *E. singularis* are common species in the bay but they do not form dense populations as those in the western Mediterrranean Sea (Topçu pers. obs.; Figure 1B). Another spot with relatively dense populations of *E. cavolini* in the Northern Aegean Sea is Gökçeada (Öztürk B., pers. comm.). Apparently, gorgonians are more common in the Northern Aegean than in the Southern Aegean Sea. Along Turkish coasts, Bodrum seems to mark the southern limit of distribution of gorgonians. At this region, dense populations of *E. cavolini* were observed sporadically (Öztürk B., pers. comm. Figure 1C).

Figure 1. *Eunicella cavolini* population in Ayvalık (A). A community with *E. singularis* and *E. cavolini* in Saros Bay (B). *Eunicella cavolini* population in Bodrum (C) (Picture C photo credit: Bayram Öztürk).

Threats and research priorities concerning corals in the Aegean Sea

Anthozoans in the Mediterranean Sea are under threat from several disturbances (e. g. fisheries pressure, pollution etc.) but recent studies show that temperature anomalies of seawater have an important role in causing mass mortalities which significantly reduce anthozoan populations. Two episodes of mass mortalities were recorded in the Western Mediterranean and anthozoan species were among the most affected organisms by these events (Cerrano *et al*. 2000; Garrabou *et al*. 2009). Among most affected organisms by mortality, *Cladocora caespitosa* (Linnaeus, 1767), *Balanophyllia europaea* (Risso, 1826) and *Parazoanthus axinellae* (Schmidt, 1862) (Garrabou *et al*. 2009) are common species along Turkish Aegean coasts (Topçu pers. obs. Fig. 2) but there are no demographic or monitoring studies that can report whether they were affected by mortalities or not. Gorgonians were also highly affected by mass mortalities. In the northern Aegean Sea, *E. cavolini* populations are characterized by low densities, high proportion of large colonies, but low number of small colonies, signifying limited recruitment (Sini *et al*. 2015). This demographic pattern coupled to low genetic diversity/high private allelic richness observed in Ayvalık region (Masmoudi *et al*. 2013) demonstrate that populations in the Aegean Sea are probably even more vulnerable against disturbances.

Figure 2. *Cladocora caespitosa* in Gökçeada (A). *Parazoanthus axinellae* (B) and *Balanophyllia europaea* (C) in Saros Bay.

The scleractinian *Cladocora caespitosa* is found on a wide range of substrates from 5 to 40 m depth (Zibrowius, 1980) and is the only endemic zooxanthellate reef-builder coral in the Mediterranean Sea (Morri *et al*., 1994). It is one of the most common anthozoans in the Aegean Sea with populations consisting generally of discrete and scattered colonies along Turkish Aegean coasts (Topçu pers. obs.). This species is under threat from global warming (Kersting *et al*., 2013; Kružić *et al*., 2014) and invasive algal species (Kružić *et al*., 2008; Kersting *et al*., 2014). Its populations in the western Mediterranean Sea underwent high mortalities related to positive thermal anomalies (Rodolfo-Metalpa *et al*., 2008; Kersting *et al*., 2013). Along Turkish Aegean coasts, there is only one study that deals with the distribution and mortality of the species in Gökçeada Island (Güreşen *et al*. 2015); this study reports relatively high mortality rates for the northern Aegean Sea where the seawater is relatively cold, also underlines a threat from harvesting, and finally suggest that *C. caespitosa* should be included in the list of species completely prohibited to harvest according to the statements 2012/66 and 2012/65 of Turkish law.

In conclusion, demographic studies are necessary in order to evaluate the current status of a population and its future trends which will then help to develop conservation plans. Gorgonians are generally used as indicators of mortality impact because they are monitored over very long years in the western Mediterranean with strong baseline data (Garrabou *et al*. 2009). In the western Mediterranean, there are many studies that demonstrate the importance of demographic and monitoring studies in order to evaluate the impact by disturbances (Coma *et al*. 2006), and constitute conservation plans (Bramanti *et al*. 2014; Montero-Serra *et al*. 2015) or restoration models (Linares *et al*. 2008). Therefore, studies on the demography and disturbance level of anthozoan species focusing on gorgonians, are necessary over the Aegean Sea.

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COMMERCIAL MOLLUSC SPECIES OF THE AEGEAN SEA

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1. Introduction

The phylum Mollusca is one of the major groups among the invertebrates, which includes much number marine species with commercial values, and their exploitation by human either for food or for making of jewelry dating the ancient epochs. Along the world's marine coastline, human being has always had available food source, consisting of various shellfish, which have provided an easy source of food high in protein. Today, on the world, the commonly eaten molluscs are clams (Myidae and Veneridae), scallops (Pectinidae), oysters (Ostreidae), mussels (Mytilidae), whelks (Buccinidae), cockles (Cardiidae), conchs (Strombidae), pen shells (Pinnidae), top shells (Trochidae), abalone (*Haliotis* spp.), periwinkles (Littorinidae), coquinas (Donacidae), limpets (Patellidae, Fissurellidae), turban shells (Turbinidae), helmet shells (Cassidae), giant clams (Tridacnidae) and rarely some chitons.

Some mollusk species of Muricidae such as *Hexaplex trunculus*, *Rapana venosa* and *Stramonita haemastoma* have been used to produce indigo and indigoid dyes, which are used in textile, food, medicine and cosmetic sectors as a colorant. Nowadays, the new analogous of those substances are synthesizing for the treatment of some important diseases as cancer and diabetes (Demirbağ *et al*., 2014). On the other hand, cowrie and helmet shells have been used as decoration stuff.

Although much number of molluscan species are intensively consumed on the world, a limited number of species such as *Loligo vulgaris*, *Octopus vulgaris, Sepia officinalis* and *Mytilus galloprovincialis* are preferred as seafood in Turkey, due to the people's consumption habits. List of the molluscan species which are fished in the Turkish Seas are given in Table 1. Some species such as *Rapana venosa*, *Chamelea gallina*, *Ruditapes decussatus* and *Venus verrucosa*, obtained from natural habitats by fishing, have been mostly exported to different European countries. In the domestic market, *R. venosa* has mainly been used to produce of bone meal.

In Turkey, total product of molluscs obtained either by fishing or aquaculture between the years of 2000 and 2014 consisting mainly of *Rapana venosa*, *Mytilus* *galloprovincialis*, *Modiolus barbatus*, *Chamelea gallina*, *Ruditapes decussatus* and *Sepia officinalis* vary between 12.115 t/year and 74.325 t/year. The biggest tonnage was obtained in 2012, and the last two years there is a considerable reduction in the mollusc production (Figure 1). In the all years, the biggest part comprises both together *Ruditapes decussatus* and *Chamelea gallina*, except for the year 2005, when the production of *M. galloprovincialis* and *M. barbatus* is in a greater quantity.

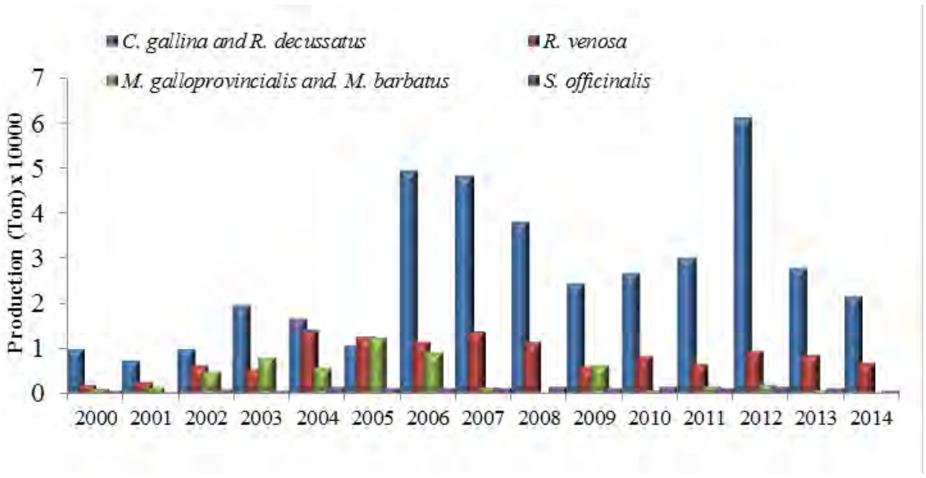

Figure 1. Total production of some molluscs in Turkey between the years 2000-2014 (t/ year) (Anonymous, 2015a).

Among different molluscs having commercial interest and fishing in the Aegean Sea, *Sepia officinalis* stands out as the most abundant species caught, following by the other cephalopod species (Table 1). Total production of *Chamelea gallina* in Turkey originated in the Black Sea only. *Rapana venosa* is fished mainly in the Black Sea and the Sea of Marmara. There is also a production in low quantity of the species in the northern Aegean Sea.

Table 1. The quantity of production of some molluscs with commercial value according to the Turkish coasts (Anonymous, 2013).

Species	Turkish Coasts			
	Levantine Sea	**Aegean Sea**	**Sea of Marmara**	**Black Sea**
Rapana venosa	-	4.10	327	8321.7
Mytilus galloprovincialis	-	40.9	13.3	833.2
Pecten jacobeus	-	-	3	-
Ostrea edulis	-	-	11.2	-
Chamelea gallina	-	-	-	28029.7
Ruditapes decussatus	-	83.4	-	-
Loligo vulgaris	235.9	251.7	3.7	-
Octopus spp.	61.9	219.9	1.8	-
Sepia officinalis	974.8	267.5	1.8	-

2. Species with Major Commercial Interest Produced in the Turkish Aegean Coasts
Classis Gastropoda

***Hexaplex trunculus* (Linnaeus, 1758)**

Hexaplex trunculus (the banded dye-murex) (in Turkish: madya or madya purpur) is a species of medium sized molluscs, having a broadly conical shell with a spire of angulated whorls (Figure 2). The sculpture on the last whorl consists of 4-8 narrow and nodose axial ribs with short spines at shoulder. Spines may be reduced or obsolete in some specimens. There is also a spiral sculpture of cords and threads. Aperture large and roundly-ovate. Outer lip crenulate, columellar lip narrow and smooth. Its color vary from specimen to specimen, but usually with 2 or 3 dark colored spiral bands on the body whorl. Shell can grow up to 10 cm in height.

The species is distributed both throughout the Mediterranean and in the eastern Atlantic Ocean near the Gibraltar Strait. In the Turkish seas, it is distributed along all the coasts, except for the Black Sea. The species can be encountered from littoral rocks to 120 m, usually at 0.3-30 m depth, on rocky shores (Houart, 2001).

Figure 2. *Hexaplex trunculus*: frontal view of three different specimens (h=50-72 mm)

The species is important because of the mucus secreting of its hypobranchial gland and using to produce indigo or indigoid dyes. It is known that the ancient Phoenicians used this secret as a distinctive purple-blue indigodye. *Hexaplex trunculus* has also been used as fishing bait. Although the species is known to be marketing as a fish bait, there is no statistical information for its production in Turkish seas.

***Rapana venosa* Valencienne, 1846**

Rapana venosa (veined rapa whelk) (in Turkish: Deniz Salyangozu) is a big sized mollusc species reaching up to 200 mm and more in height (Houart, 2001). Shell with a short spire and consisting mainly of body whorl (Figure 3). There is a sculpture of axial ribs and smooth spirals. Aperture large and ovate. Small elongated teeth on the outer lip margin internally. Shell color varies from gray to reddish brown, with dashes on the spiral ribs being dark brown in color. Inside of the aperture and on the columella the color is deep orange.

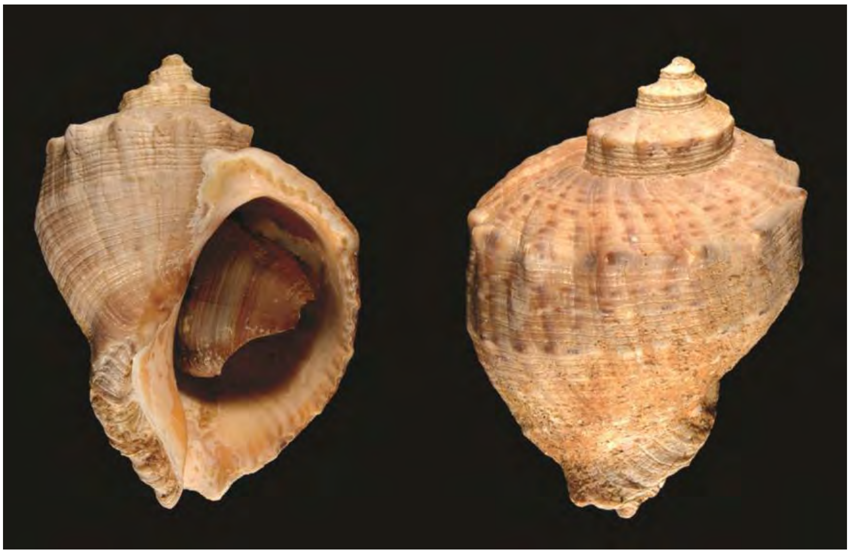

Figure 3. *Rapana venosa*: frontal and dorsal views of a specimen (h= 70.8 mm)

The species is carnivorous and its main diet consists of bivalve molluscs such as oysters, venerids (*Chamelea gallina*) etc. *Rapana venosa* smothers their prey by wrapping around the hinged region of the shell and feeding between the opened valves.
Rapana venosa is a wide spread gastropod along the world's coastline, which is native to the marine and estuarine waters of the western Pacific Ocean. Since the 1940's it is known to be distributed in the Black Sea and, at the present day, the species has a large population in the Black Sea. Along the Turkish coasts, along with the Black Sea coast, the species is also distributed in the Sea of Marmara and northern Aegean Sea (Öztürk *et al*., 2014). Its population in the Aegean Sea is rather limited compared to the Black Sea.

The production of the species is based on fishing on the native habitats, and the product mainly originated in the Black Sea has a commercial interest, where the species is abundant. Total production in 2013 was 8654 tons and 96 % of the product originated from the Black Sea (Figure. 4). No records of the species along the Levantine coast of Turkey.

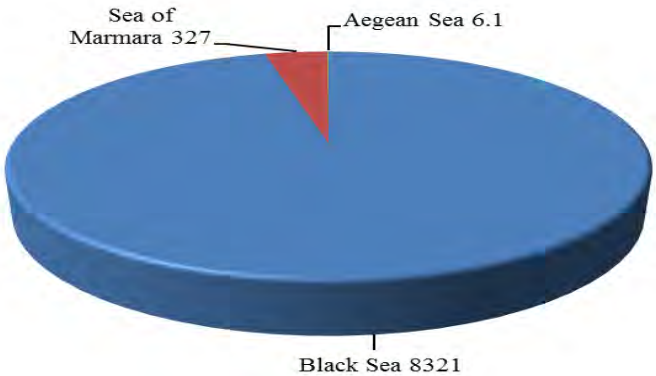

Figure 4. Total production of *Rapana venosa* according to the Turkish coasts in 2013 (ton) (Anonymous, 2013).

Classis Bivalvia
***Mytilus galloprovincialis* Lamarck, 1819**

Mytilus galloprovincialis (Figure 5) which is called as "Kara Midye" or "Akdeniz Midyesi" in Turkey is a widespread Mediterranean and Black Sea species. Since, *M. galloprovincialis* has become invasive in many parts of the world (Bownes and McQuaid, 2006) and due to the confusion with *Mytilus edulis*, which is a very similar congeneric species, the exact distribution range of *M. galloprovincialis* is not clear. It lives in the intertidal and infralittoral zones and, attached by strong byssus threads to almost any kind of hard substrates, i. e., rocks, jetty piles, underwater ropes of the marine constructions, hulls of the ships etc… Its specimens generally have 6-8 cm length while occasionally some specimens may reach 15 cm due to the ecological conditions of the inhabited area. *Mytilus galloprovincialis* is a filter feeding bivalve and may constitutes beds especially in organically rich sites and can even reach maximum of 77 175 individuals and 24.210 g biomass/m^2 (Çınar *et al*. 2008). Turkey is one of the main countries producing the species from the native habitats in the Mediterranean and Black Seas. The species are collected generally by divers. Production of *M. galloprovincialis* in Turkish seas mainly based on the natural populations but aquaculture has become another important method of production in the last decade (Figure 6) (Anonymous, 2015a). According to Anonymous (2015b), production of *M. galloprovincialis* in the Aegean coasts of Turkey has shown a fluctuation between 1975 and 2013 (Figure 7). İzmir Bay is represented with the densest natural populations of *M. galloprovincialis* along the Aegean coasts of Turkey due to its unique hydrographic and ecological properties. Although the commercial molluscs are not consumed frequently in Turkey, *M. galloprovincialis* is very popular as stuffed mussel (Figure 8) especially in the western part of Turkey.

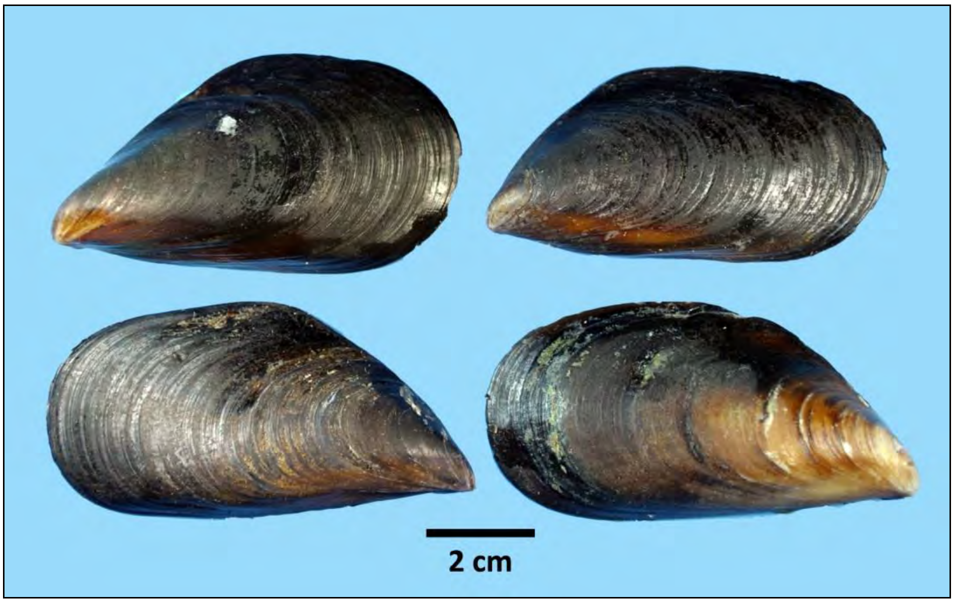

Figure 5. General view of the specimens of *M. galloprovincialis*.

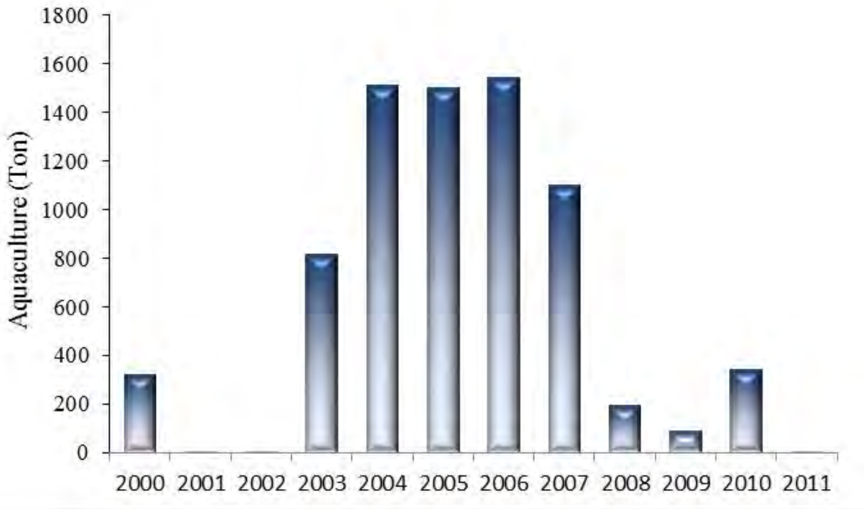

Figure 6. Aquaculture quantity of *M. galloprovincialis* in Turkey (Anonymous, 2015a).

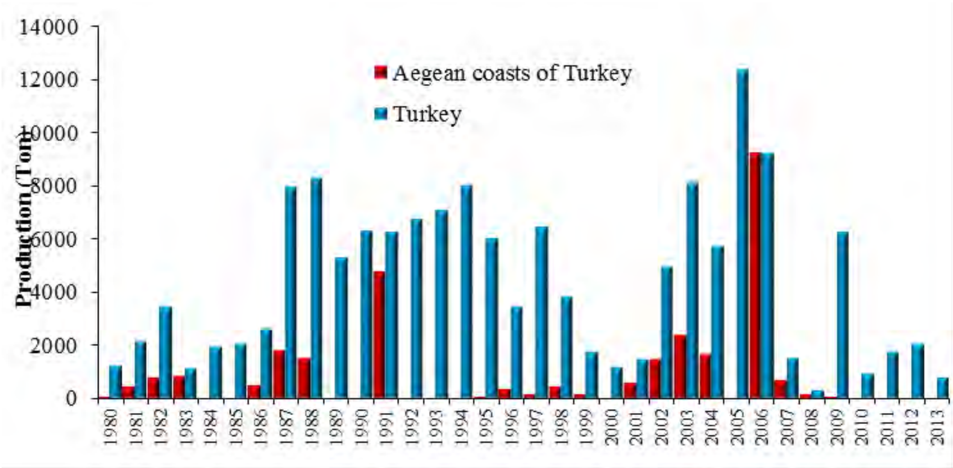

Figure 7. Production of *M. galloprovincialis* in Turkey and in the Aegean coasts of Turkey (Anonymous, 2015b).

Figure 8. *M. galloprovincialis* as stuffed mussel.

Ostrea edulis **Linnaeus, 1758**

The European flat oyster *Ostrea edulis* (Figure 9) which is called as "İstiridye" in Turkey is one of the commercial species whose production in Turkey hinge on the natural populations only. This species is known from all over the Mediterranean and the Black Sea, and from the coasts of Europe from Norway to Morocco. *Ostrea edulis* is a sessile species typically cements itself by the left (lower) valve to the hard substrates permanently at early stages of its life. It lives in shallow coastal waters down to a depth of 90 m. The general shape of the shells is roughly circular to oblong in outline but irregularities can be seen due to the structure of the substratum on which the species attaches itself. Length is usually up to 10 cm but occasionally it can reach 20 cm and this may take 20 years (Anonymous, 2015b). Like other oysters, *O. edulis* filters phytoplankton and other particulate material from the seawater. This species is harvested by divers. On the other hand, the production of *O. edulis* both in Turkish seas and the Aegean coasts of Turkey show prominent decrease in the last 10 years (Figure 10) (Anonymous, 2015b). Over-fishing might be the most important factor affecting the declining of *O. edulis*' populations along the Turkish coasts.

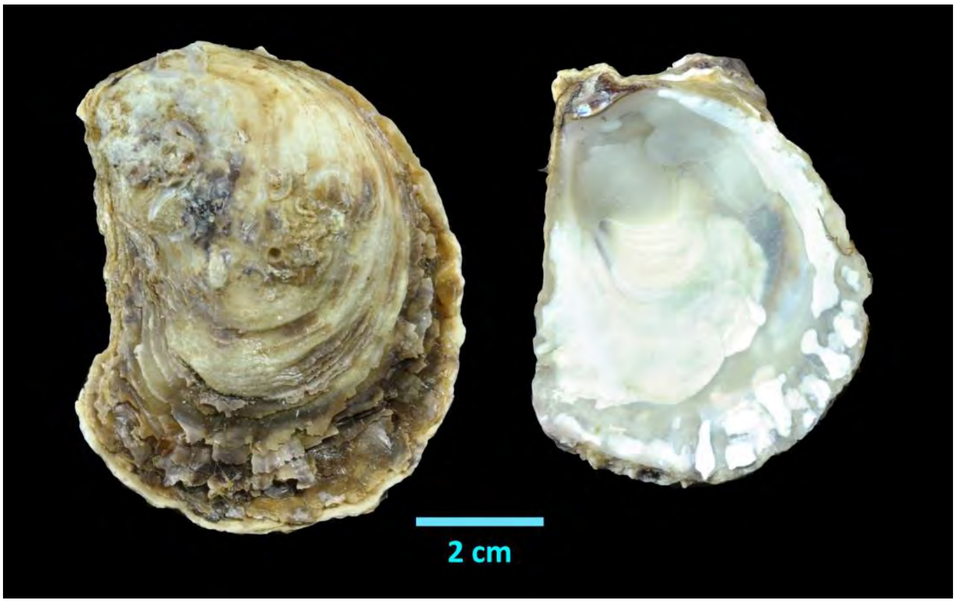

Figure 9. General view of specimens of the European flat oyster *Ostrea edulis*

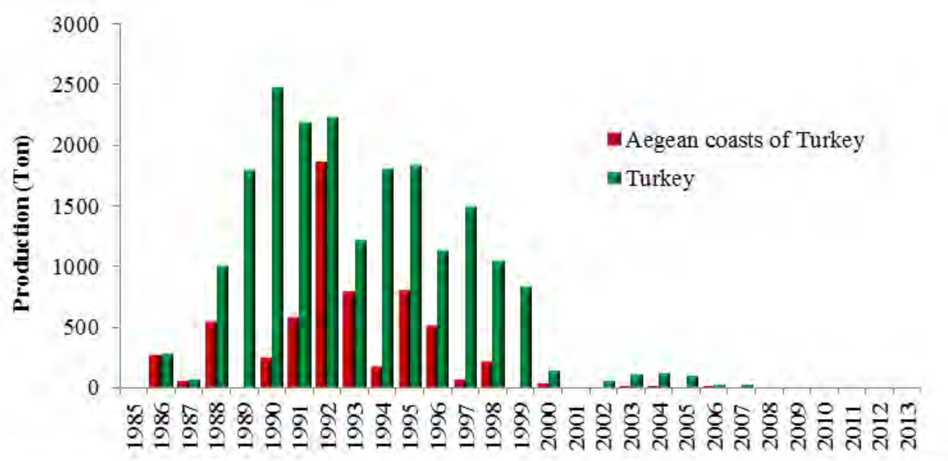

Figure 10. Production of *O. edulis* in Turkey and in the Aegean coasts of Turkey (Anonymous, 2015b).

***Chamelea gallina* (Linnaeus, 1758)**

The Stripped Venus Clam, *Chamelea gallina* (Figure 11), named as "Beyaz Kum Midyesi" or "Cik Cik" in Turkey, is one of the most important commercial bivalve species of the family Veneridae in the Mediterranean Sea. Among the molluscan species produced in the Turkish seas, it is the species with the highest production value. (Anonymous, 2015a). *Chamelea gallina* is distributed in the Mediterranean and Black Seas, and the European and north-western African coasts of Atlantic, from Norway to Morocco; also known from Madeira and the Canary Islands. The species is a filter feeding one feeding on microalgae, bacteria, and small detritic particles and prefers the clean sandy or muddy sand bottoms in the infralittoral zone. The Stripped Venus Clam is usually 2.5-3.5 cm in length but occasionally may grow up to 5 cm. Harvesting of this species is conducted by means of fishing vessels equipped with hydraulic dredging systems. Its exploitation is very limited in the Aegean coasts of Turkey (Figure 12), and the species has mainly been fished from the native habitats in the Sea of Marmara. Due to the absence of the domestic consumption, the great majority of the production is exported to European Union countries as frozen or canned goods (Dalgıç *et al.*, 2010).

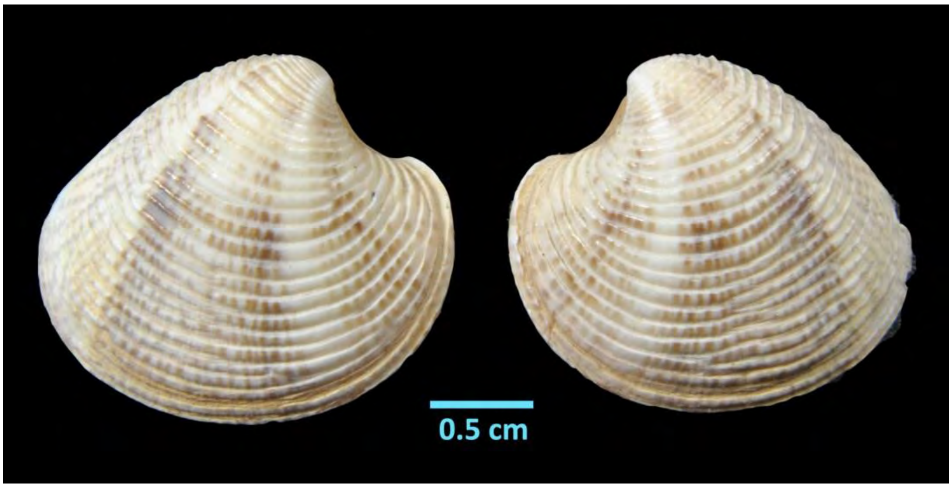

Figure 11. The general view of a specimen of *Chamelea gallina*

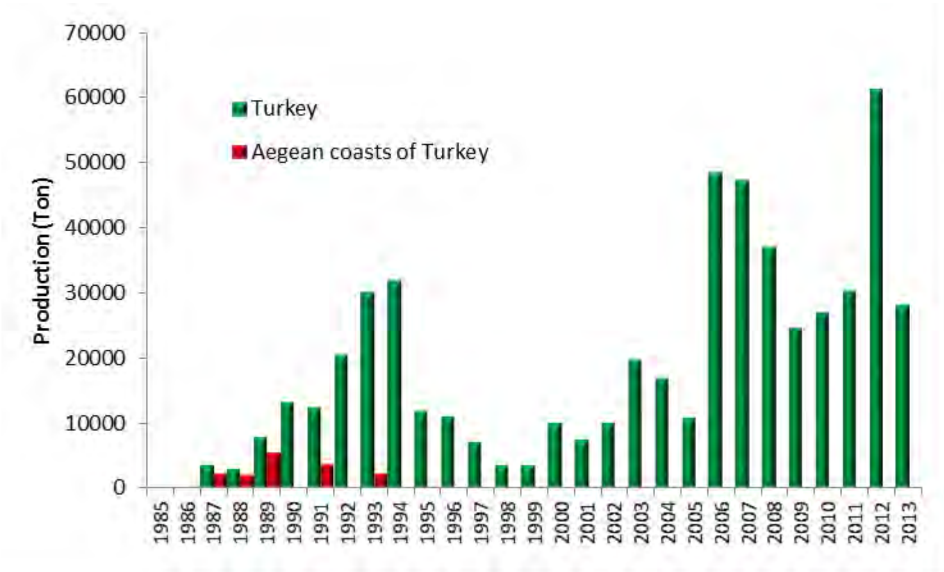

Figure 12. Production of *C. gallina* in Turkey and in the Aegean coasts of Turkey (Anonymous, 2015b).

***Ruditapes decussatus* (Linnaeus, 1758)**

The Carpet Shell, *Ruditapes decussatus* (Figure 13), which is called as "Akivades" in Turkey is one of the most important commercial bivalve mollusc harvested especially along the Aegean coasts of Turkey. *Ruditapes decussatus* is a cosmopolitan species occurring on the west European and African coasts, from the British Islands to Senegal, also in the Mediterranean, even recorded from the Suez

Canal and the Red Sea as an anti-Lessepsian species (Barash and Danin, 1992). The species is a filter feeding bivalve preferring sandy or muddy sand bottoms of the infralittoral zone and coastal lagoons and evaluated as the indicator of polluted areas. It usually grows up to 4-5 cm in length but sometimes it may reach up to 8 cm in length (Fischer *et al*., 1987). Almost all of the harvesting of *R. decussatus* along the Turkish seas is conducted in the Aegean coasts of Turkey at the five production area determined by the Ministry of Food, Agriculture and Livestock located in İzmir and Balıkesir. Fishermen in İzmir Bay use special shovel and sieve in order to capture the specimens of *R. decussatus* (Figure 14). On the other hand, there is a dramatic decrease of the production of the species in the Aegean coasts of Turkey during the last decade (Anonymous 2015a) (Figure 15).

Figure 13. General view of specimens of *Ruditapes decussatus.*

Figure 14. Harvesting of *R. decussatus* in İzmir Bay with a shovel and sieve

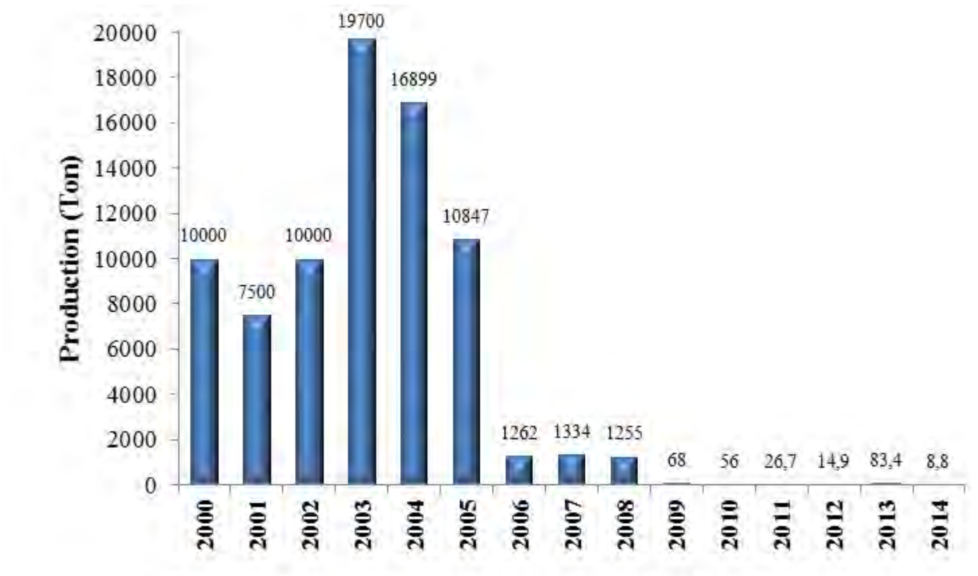

Figure 15. Production of *Ruditapes decussatus* along the Aegean coasts of Turkey (Anonymous, 2015a).

Classis Cephalopoda
***Sepia officinalis* Linnaeus, 1758**

The common cuttlefish *Sepia officinalis* which is named as “Sübye” or “Mürekkep Balığı” in Turkish, occurs along the eastern Atlantic and Mediterranean coasts (Pierce *et al*., 2010) (Figure 16). In the Turkish seas, the species is distributed in the Sea of Marmara, Levantine and Aegean Seas coasts of Turkey (Demir, 1952; Katağan and Kocataş, 1990; Salman and Katağan, 2004). It is demersal species which is found at sandy and muddy bottoms with sea meadows up to 200 m. The maximum mantle length is 45 cm. *Sepia officinalis* has seasonally vertical migration for spawning and nursery. This cuttlefish feeds on small crabs, shrimps, polychaetes, nemertini, demersal fishes and some molluscs. In addition, cannibalism is common in *S. officinalis* at all sizes (Salman *et al*., 1998). There are three commercial species of the genus *Sepia* (*S. officinalis* Linnaeus, 1758, *S. elegans* Blainville, 1827, *S orbignyana* Ferrussac, 1826) distributed along the Turkish coasts. The production data of common cuttlefish caught in Turkish seas mentioned by Food and Agriculture Organisation of the United Nations (FAO) and Turkish Statistical Institute (TUIK) corresponds to *S. officinalis* only. It attracts attention that the production of cuttlefish is represented with the most quantity among the production values of the cephalopods exploited in Turkey, likewise in the Mediterranean (Anonymous, 2015a; Pierce *et al.*, 2010). The major part of the invertebrate exploitation belongs to *S. officinalis* in Turkey (1.7% in 2012, 2.8% in 2013 and 1.99% in 2014) (Anonymous, 2015a). Since the year 1975, the highest production values of this cuttlefish were obtained in 1989 (2279 ton/year) and 1990 (2059 ton/year) respectively in the Aegean coasts of Turkey (Figure 17). According to IUCN Red list and Barcelona/Bern Conventions, it is an endangered species due to its overfishing.

Figure 16. General view of a specimen of *Sepia officinalis*(Photographed by Baki YOKEŞ)

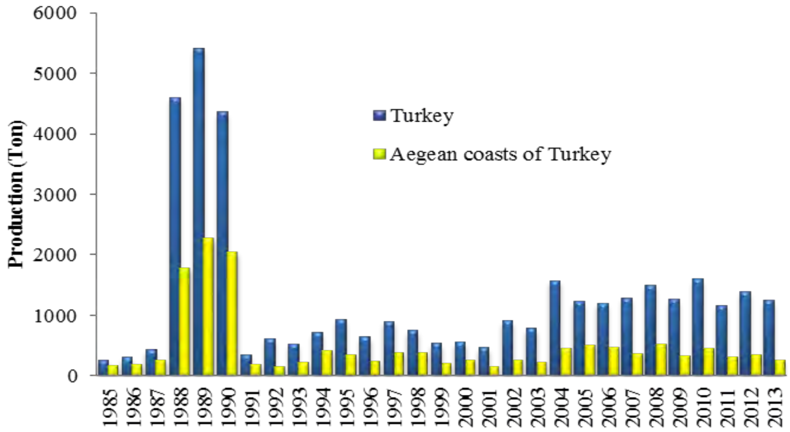

Figure 17. Production of *S. officinalis* both in Turkey and in the Aegean coasts of Turkey (Anonymous, 2015b).

Loligo vulgaris Lamarck, 1798

The European squid or common squid *Loligo vulgaris* extends through the eastern Atlantic, North Sea and Mediterranean Sea (Salman *et al.*, 1998) (Figure 18). The species is called as “kalamar” in Turkey and known from the all the coasts of Turkey, except for the Black Sea (Digby, 1949; Katağan and Kocataş, 1990; Salman and Katağan, 2004). The squid, which is a nectobenthic species, is distributed at depth range between 11 and 250 m (Öztürk *et al*., 2014) and performs vertical and horizontal migrations due to environmental factors. There are differences between the mantle length of the male (with 42 cm maximum mantle length) and female (with 32 cm maximum mantle length) individuals (Salman *et al*., 1998). Pierce *et al*. (2010) was stated that the paralarvae of this squid feed on crustacean larvae, fish larvae and mysids. It is usually caught by squid baits, bottom and pelagic trawls. In the last decade, the maximum production (667 ton/year) of the common squid in the Turkish Aegean Sea was performed in 2007 (Figure 19). *Loligo vulgaris* is one of the most preferred sea food mostly served fried (Figure 20) in the fish restaurants in Turkey.

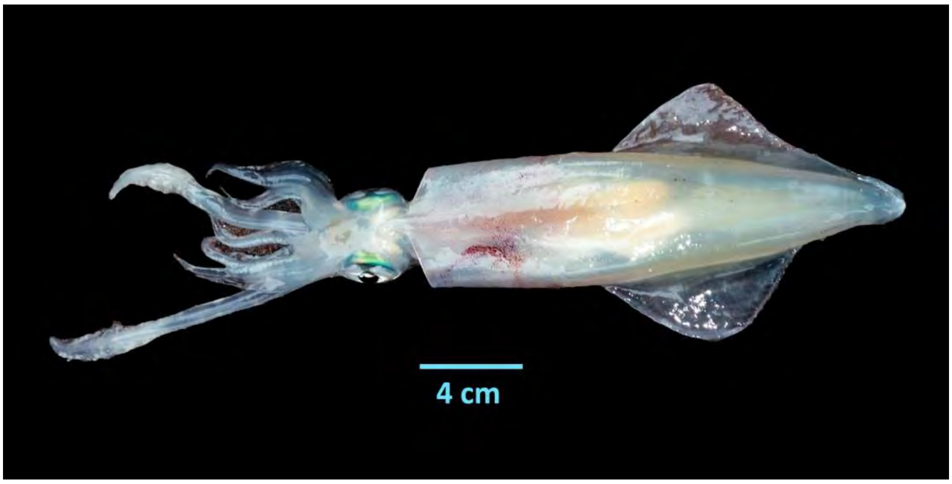

Figure 18. General view of a specimen of *Loligo vulgaris*

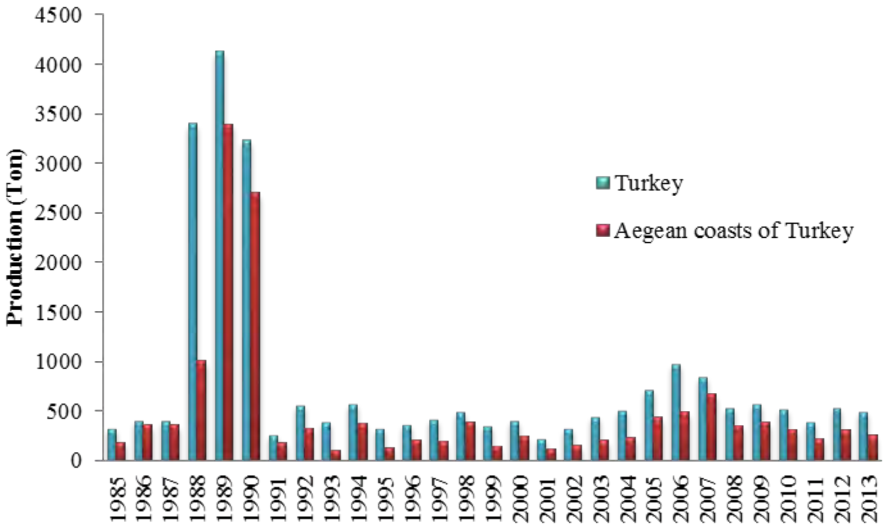

Figure 19. Total production of *L. vulgaris* in Turkey and in the Aegean coasts of Turkey (Anonymous, 2015b).

Figure 20. *Loligo vulgaris,* one of the most preferred sea food in the fish restaurants

***Octopus vulgaris* Cuvier, 1797**

The common octopus *Octopus vulgaris*, which is called as “Ahtapot” in Turkish, is a cosmopolite species (Figure 21) and it is found among the first recorded molluscs from the Turkish coasts by Forsskål (1775). As the common squid and the common cuttlefish, the species is also known to be distributed along all the coasts of Turkey, except for the Black Sea (Degner, 1925; Salman and Katağan, 2004). *Octopus vulgaris* is a demersal species inhabiting rocky, coralligenous or sandy bottoms up to the 200 m depth and performs seasonal migrations in order to reproduce. The males are bigger than female and mantle length grows up to 23 cm (Salman *et al.*, 1998). Diet of adults comprises polychaetes, crustaceans, teleost fishes, bivalves and other cephalopods (Pierce *et al*., 2010). *Octopus vulgaris* is mainly fished by means of bottom and pelagic trawls, pots, trammel nets and traps. In the last three decades, the maximum production of common octopus (1574 ton/year) in the Aegean coasts of Turkey was obtained in 1989 (Figure 22). But its production in Turkey has gradually been decreased since 1998 (Figure 22), most probably due to the over-fishing.

Figure 21. A view of a specimen of *Octopus vulgaris* in its natural habitat (Photographed by Melih Ertan ÇINAR)

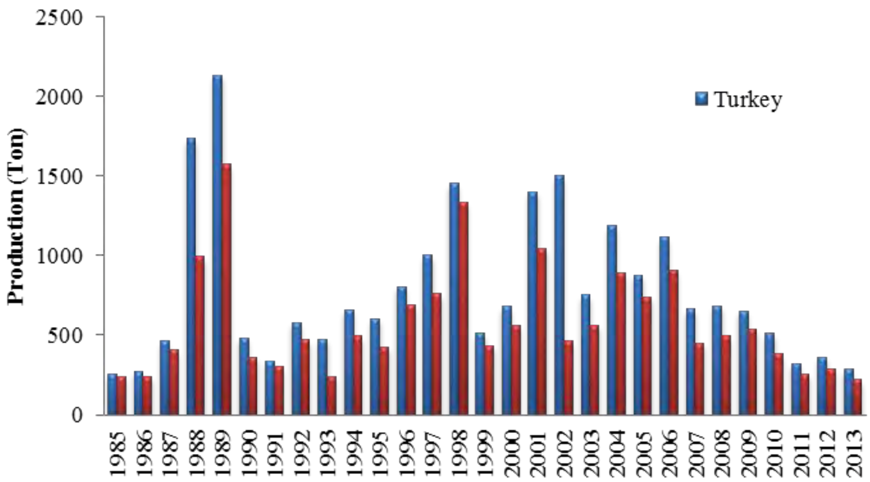

Figure 22. Production of *O. vulgaris* in Turkey and in the Aegean coasts of Turkey (Anonymous, 2015b).

Besides the species having major commercial importance mentioned above, there are some other native and exotic molluscan species (Table 2) which are known to be distributed along the Aegean coasts of Turkey having major or minor commercial value. Those species have not been fished in the Turkish coasts of Aegean Sea most probably due to the absence of domestic consumption habits in Turkey and lacking of exploitable populations. Their exploitation might be performed at the future if they begin to be preferred by the Turkish people as seafood. Moreover, exploitation of some commercial important species e.g., *Lithophaga lithophaga, Pinna nobilis* and *Tonna galea* are regulated or forbidden within the frame of National or International rules.

Table 2. The list of native and exotic molluscan species distributed along the Aegean coasts of Turkey having major or minor commercial value.

Patella caerulea Linnaeus, 1758	*Spisula subtruncata* (da Costa, 1778)
Phorcus articulatus (Lamarck, 1822)	*Donacilla cornea* (Poli, 1791)
Phorcus turbinatus (Born, 1778)	*Donax trunculus* Linnaeus, 1758
#*Cerithium vulgatum* Bruguière, 1792	*Gari depressa* (Pennant, 1777)
**Conomurex persicus* (Swainson, 1821)	*Solecurtus strigilatus* (Linnaeus, 1758)
#*Luria lurida* (Linnaeus, 1758)	*Callista chione* (Linnaeus, 1758)
#*Tonna galea* (Linnaeus, 1758)	*Dosinia exoleta* (Linnaeus, 1758)
#*Ranella olearium* (Linnaeus, 1758)	*Venus verrucosa* Linnaeus, 1758
Charonia variegata (Lamarck, 1816)	#*Pholas dactylus* Linnaeus, 1758
Bolinus brandaris (Linnaeus, 1758)	*Solen marginatus* Pulteney, 1799
Stramonita haemastoma (Linnaeus, 1767)	*Ensis minor* (Chenu, 1843)
Conus ventricosus Gmelin, 1791	#*Sepia orbignyana* Ferrussac,1826
Arca noae Linnaeus, 1758	#*Sepia elegans* Blainville,1827
Barbatia barbata (Linnaeus, 1758)	*Loligo forbesi* Steenstrup,1856
Modiolus barbatus (Linnaeus, 1758)	*Illex coindetii* (Verany,1839)
#*Lithophaga lithophaga* (Linnaeus, 1758)	*Todarodes sagittatus* (Lamarck,1798)
#*Pinna nobilis* Linnaeus, 1758	#*Eledone cirrhosa* (Lamarck,1798)
**Pinctada radiata* (Leach, 1814)	*Eledone moschata* (Lamarck,1799)
Aequipecten opercularis (Linnaeus, 1758)	*Alloteuthis media* (Linnaeus,1758)
Flexopecten glaber (Linnaeus, 1758)	*Todaropsis eblanae* (Ball,1841)
Pecten jacobaeus (Linnaeus, 1758)	#*Rossia macrosoma* (Della Chiaje,1830)
Mimachlamys varia (Linnaeus, 1758)	#*Rondeletiola minor* (Naef,1912)
Spondylus gaederopus Linnaeus, 1758	#*Sepietta oweniana* Naef,1916
**Crassostrea gigas* (Thunberg, 1793)	*Scaeurgus unicirrhus* (Della Chiaje in de Férussac & d'Orbigny,1841)
Cerastoderma glaucum (Bruguière, 1789)	

*: Alien species, #: Protected species

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CEPHALOPODS OF THE AEGEAN SEA

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1. Introduction

1.1. History of Cephalopods in the Aegean Sea

Cephalopods, by becoming the monster of the sea myths and a design feature in many art subjects were successfully able to stay under the spotlight for 5000 years of human history. The humans interest for cephalopods dates back to many years before. In the years 700 BC cephalopods were mentioned in Homeros' "Odisse". In the coming years Aristo (330 BC) "*Historia Animalium*" gave a more scientific information on their detailed features and behavior of octopuses and cuttlefishes. After a long break, by Forbes (1844) and after that Degner (1925) from pelagic samplings of 4 different stations of the "*Danish Oceanographical Expeditoins of 1910*" came across with cephalopod species. Afterwards the study by Katagan and Kocataş (1991) of Turkey's Aegean coasts, and then D'Onghia *et al.* (1992) reported information on cephalopod distribution and abundance of 500 m in depth of the North Aegean Sea international waters and around Limni Island. Following them Salman *et al.* (1997) reported the distribution and catch per unit effort of cephalopod species till 500 m in depth as a part of a project sampling demersal fish stocks of Turkish waters and international waters of Aegean Sea with a bottom trawl. In subsequent Aegean Sea teuthological studies continued with Lefkaditou *et al*. (2003) and Lefkaditou and Kaspiris (2005). On cephalopod paralarve the first study was done by Degner (1925), afterwards from North Aegean Sea Lefkaditou *et al*. (1999) and then from Turkish waters of Aegean Sea studies by Salman *et al.* (2003) and Salman (2012) can be seen.

In Salman (2009) study, which is one of the latest faunistic study, reviewed what type of studies on cephalopod species (such as systematic, juvenile distribution, abundance, stomach content, reproductive biology, fecundity etc.) were conducted in different parts of Eastern Mediterranean and consequently the Aegean Sea.

1.2 Current Status of cephalopods in the Aegean Sea

Except the order Vampiromorpha belonging to subclass Coleoidea rest of the four orders of class Cephalopoda inhabits the Mediterranean. These orders are Sepiida the cuttlefishes, Sepiolida the pigmy cuttlefishes, Teuthida the squids and Octopoda the octopuses (Figure 1).

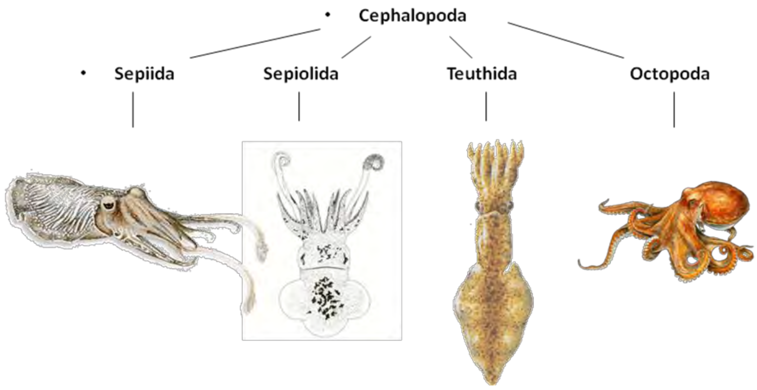

Figure 1. Systematic groups of cephalopods inhabiting Mediterranean.

Cephalopods are organism which are sensitive to salinity therefore stenohalin. Because of this when there is no cephalopod inhabiting the Black Sea, in the Sea of Marmara just because of the current system where the Aegean Sea is effective limited species inhabit these waters in a faunistic sense (Katagan *et al*., 1993). This made Sea of Marmara a core area for cephalopod fauna biodiversity as Aegean Sea being the base, and the Dardanelle Strait a corridor connected to Sea of Marmara.

According to Salman *et al*. (2002), a study aiming to identify the teuthofauna of Turkish seas, there are 47 cephalopod species inhabiting Aegean Sea. Than Salman *et al*. (2003) contribution with juvenile specimens of *Thysanoteuthis rhombus* and *Brachioteuthis riisei* and Bello and Salman (2015) with *Sepiola boletzkyi* a new record for Aegean Sea, the species count increased to 50. With the revision of the Octopoteuthidae family of the Mediterranean by Jereb *et al*. (inpress) revised the species number to 49 in Aegean Sea as a result of identification of *Octopoteuthis megaptera* species to *Octopoteuthis sicula*, which collaborates to almost 90 % of the Turkey' cephalopod fauna. As reported by Bello (2003); to the 65 cephalopod species inhabiting Mediterranean with additions of 2 new species, *Sepiola bursadhaesa* from Catalan Sea (Bello, 2013), and *Sepiola boletzkyi* from Aegean Sea (Bello and Salman, 2015), the total fauna increased to 67 species. In conclusion in Aegean Sea, a more oligotrophic sea compare to Mediterranean, when kept in mind that the scarcity of the faunistic studies on cephalopods, Aegean Sea fauna compiles give or take 75 % of the Mediterranean fauna. In general cephalopod species exist in between the depths of the surface water to 900-1000 m according to the examination of the vertical distribution of the species inhabiting Aegean Sea where fishery is active. The cephalopod species and the vertical distribution in Aegean Sea are listed below (Table 1).

The percentages of the species to the fauna inhabiting Aegean Sea were estimated as cuttlefishes 33 %, squids 43 % and octopuses is 24 %.

When the deep sea and pelagic cephalopods inhabiting Aegean Sea are compared with the species in Mediterranean it is observed that the number is lower. It is thought to be the result of the low number of studies conducted in deep waters of our seas.
Figure xx. An adaptation of Lefkaditou (2007) cephalopod species and their vertical distribution in the Aegean Sea.

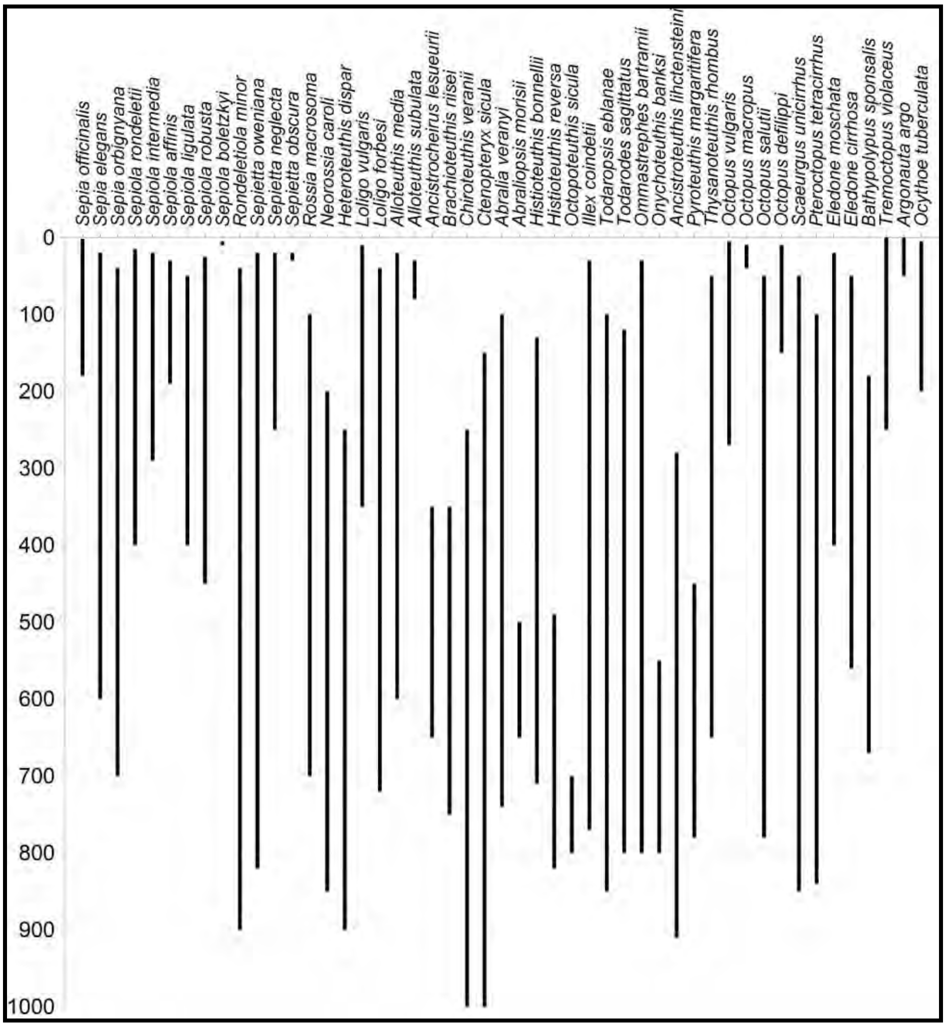

Figure 2. An adaptation of Lefkaditou (2007) cephalopod species and their vertical distribution in the Aegean Sea.

One of the important role of cephalopods in ecosystem is their predator/prey relationship. From few studies conducted on cartilaginous fishes stomachs Kabasakal (2002) (*Galeus melastomus, Scyliorhinus canicula, Mustelus mustelus* and *Raja clavata*); on big predator fishes Salman (2004) and Peristeraki *et al*, (2005) (*Xiphias gladius*) and on marine mammals stomach contents Salman *et al*, 2001 (*Monachus monachus*) reports and identifies cephalopods position in predator/prey relations in the Aegean Sea;

Out of 49 cephalopod species inhabiting Aegean Sea 24 species were identified in marine predators stomach contents. Among these studied species it was observed that sword fishes (*Xiphias gladius*) mostly prefers pelagic species (*Heteroteuthis dispar, Histioteuthis bonnellii, H. reversa, Ancistroteuthis lichstensteini, Abralia verany, Ocythoe tuberculata, Tremoctopus violaceus* and *Argonauta argo*) and that cartilaginous species mostly prefers demersal cephalopod species (*Sepia elegans, S. officinalis, S. orbignyana, Sepietta oweniana, Loligo vulgaris, Illex coindeti, Todaropsis eblanae, Todarodes sagittatus*). Also from the stomach contents of 2 stranded striped dolphin (*Stenella coeruleoalba*) beaks of *Illex coindetii* were identified (Unpublish data).

The list of cephalopod species identified from various stomach content studies from Aegean Sea is given in Table 1.

Table 1. List of cephalopod species identified from various stomach content studies from Aegean Sea

SPECIES	Salman et *al*, 2001	Kabasakal, 2002	Salman 2004	Peristeraki *et al*, 2005	Eronat and Özaydın 2014	Present study
Sepia officinalis	+	+	+			
Sepia elegans		+				
Sepia orbignyana		+			+	
Sepietta oweniana		+	+			
Sepiola robusta			+			
Sepiola intermedia			+			
Heteroteuthis dispar			+			
Sepiolidae				+		
Loligo vulgaris		+	+	+		
Loligo forbesi			+			
Alloteuthis media			+		+	
Ommastrephidae				+		
Illex coindetii		+	+	+	+	*+
Todaropsis eblanae		+	+			
Todarodes sagittatus		+	+	+	+	
Ommastrephes bartramii			+			
Histioteuthis bonnellii			+	+		

Histioteuthis reversa				+		
Enoploteuthidae			+			
Abralia verany				+		
Ancistroteuthis lichstensteini			+			
Octopus macropus			+			
Bathypolypus sponsalis	+					
Eledone moschata	+		+			
Ocythoe tuberculata				+		
Tremoctopus violaceus			+			
Argonauta argo			+	+		

*Stranded *Stenella coeruleoalba* stomach in İzmir bay (Aegean Sea).

2. Cephalopods Fisheries

From the data of Turkey's total cephalopod catch of 2013 (2019 ton) with a 36.6 % Aegean Sea cephalopod catch (738 ton) in second after Mediterranean part of Turkey. Among the annual fisheries in Aegean Sea the average is close to 2.5 %.

The main fished groups are cuttlefish, squid and octopus where cuttlefish being the first in the list (Figure 1). Then squid and octopus follows, subsequently. The catch contribution of cephalopods inhabiting Aegean Sea to the total cephalopod catch of Turkey is obviously higher compared to other areas except with cuttlefish but with squid and octopus catch. In Aegean Sea octopus with the highest value is *Octopus vulgaris* and *Eledone* species are rarely valued. Even though the catch percentage of octopus in Aegean Sea comes last it compiles the 77.5 % of the Turkish octopus catch.

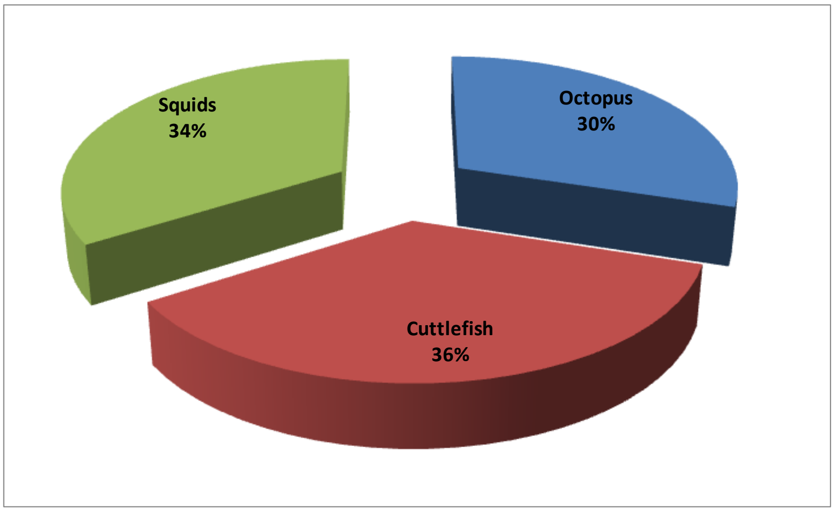

Figure 3. Distribution of the cephalopod groups caught in the Aegean Sea

Economical species are from squids are generaly *Loligo vulgaris, Loligo forbesi, Illex coindetii* and from cuttlefishes *Sepia officinalis* and rarely caught with *Sepia orbignyana*. Even though they are commercial valued species in some Europe countries species from Sephiolidae such as *Sepiola spp, Sepietta spp, Rossia macrosoma* and *Neorossia caroli* are caught by trawl net in Turkish coasts of Aegean sea, but they have no commercial value (discarded species) in Turkey. However, these discarded species are used as fresh or frozen fish meal in aquaculture facilities for some years. Commercial catch of cephalopods in Aegean Sea is 1 % of total commercial catch in the Mediterranean.

Fishing of commercial cephalopod species such as *Sepia officinalis, Loligo vulgaris Octopus vulgaris* and *Eledone moschata* is carried out intensively between 0 m and 50 m. Some other commercial cephalopods such as *Illex coindetii* ve *Sepia orbignyana* are caught as by-catch between 150 m and 350 m by shrimp trawls, *Parapenaeus longirostis.* The first study for stock assessment of cephalopods in the Aegean Sea was designed for seasonal comparison of catch per unit effort (CPUE) between 0-500 m in depth of western and eastern Aegean Sea by D'Onghia *et al.* (1992). Results show that eastern side has more yielding numbers than western side. CPUE was between 2.66 – 6.65 kg/h (min-max) in the northeastern Aegean Sea, while it was between 4.28 – 7.93 kg/h (min-max) for the western side. Another seasonal comparison study by Salman *et al.* (1997) in north and south of the Aegean Sea between 0 m - 500 m in depth showed that CPUE for cephalopods is more yielding in the northern side than the southern side. CPUE was between 3.04 – 5.90 kg/h (min-max) in the northern Aegean Sea, while it was between 2.84 – 4.45 kg/h (min-max) in the southern Aegean Sea.

According to the unpublished data of a project conducted in depths of 150 m and 550 m between 2008-2009 in Sığacık Bay, Aegean Sea CPUE values were 2.8 kg/h min and 6.9 kg/h max.

Catch number of Octopoda, which is one of the main taxon of Cephalopoda, was 220 tons in 2013 while it was 1044 tons in 2001 according to the fisheries statistics of Turkish Statistical Institute (TUİK) between 1967 and 2013. This information shows 5 times decreasing in amount of cephalopod fishing in last 10 years (Figure 2).

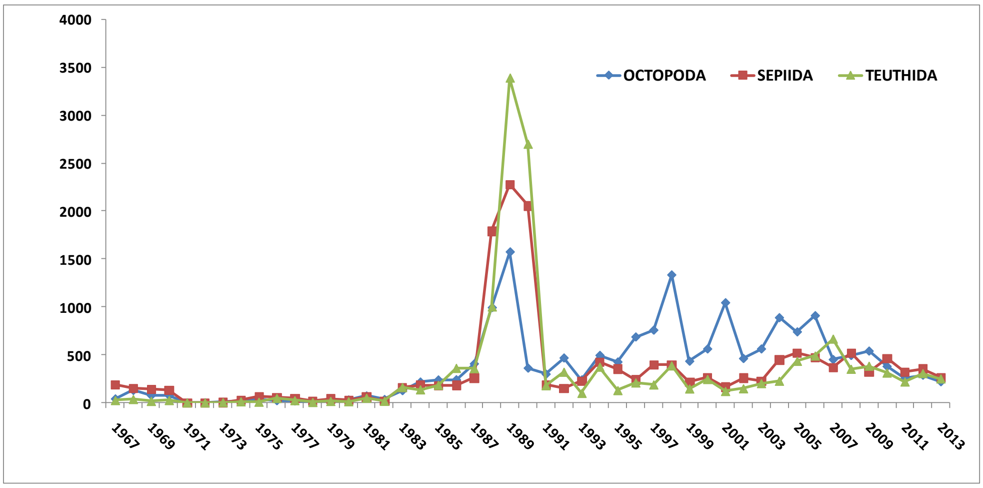

Figure 4. Amount of fishing harvest (ton) in main groups of cephalopoda between 1967 and 2013 in the Aegean Sea (TUIK).

One of the main reasons of this fact is wrong policies on cephalopod fisheries such as wrong prohibition period of the fisheries, weak controlling of the illegal fisheries activity. Species of octopus migrate to the coastal regions to nest at the rocky areas after November and spawn and care for the eggs till May. Semelpar octopus spawn once in their life span and dies after hatching of the new generation.

This annual cycle explains why numbers of octopus catch have a decreasing trend for this last 10 years (see Figure 2) and thus, it points out the impacts of the prohibition periods, which is not based on biology of the species, and is insufficiency of the controls and illegal fisheries. Unless these misapplications are corrected, it will not be possible to provide sustainable fishing of coastal octopus species, especially *Octopus vulgaris*. Sustainability of the species of octopuses, that are important for commercial purposes and nutrition, depend on understanding their biological characteristics well and reregulating the regulations on fisheries activities.

New studies are need it in the Aegean Sea to control and improve the fishing of cephalopods, to monitor the stocks systematically and to understand biology of the commercial species.

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COMMERCIAL DECAPOD AND STOMATOPOD CRUSTACEANS IN THE TURKISH AEGEAN SEA

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1. Introduction

Fishery resources of the world are determined as common property and open-access. Recently, decline in fishery resources was characterized by decreasing in total cathes and the economic fall of the fishing industry was observed in some manners (Berkes, 1986). The demersal resources on the Turkish coast have been subjected to increasing exploitation since 1960. The rapid increase in trawling capacity has resulted in the decline of the resources and operations have become less profitable.

Crustacean fisheries are mainly focused on decapods, but sometimes stomatopods constitute the target of particular fisheries. Decapod and Stomatopod crustaceans play a noticeable role in commercial fisheries in the Mediterranean Ecosystem and their roles in marine environment are more or less known.

Crustaceans such as several lobsters, portunid crabs, and penaeid shrimps are important because of their high demand in the world markets. Brachyuran crabs are most diverse regarding the number of species. Dendrobranchiate shrimps contribute to less extent to the number of species. Decapod crustaceans with commercial importance are evaluated under three major groups such as shrimps (Penaeidae, Pandalidae), brachyuran crabs (Portunidae, Majidae), squat lobsters, and lobstres (Nephropidae, Palinuridae). Penaeid shrimps are mostly distributed in tropical and warm temperate waters, on the contrary, pandalids are boreal species in distribution.

Decapod and Stomatopod fisheries on Turkish coast of the Aegean Sea may be clarified with several species such as pink shrimp, *Parapaneus longirostris* (Lucas, 1846) and Norway lobster, *Nephrops norvegicus* (Linnaeus, 1758) or other penaeid shrimps, *Aristeus antennatus* (Risso, 1816) and *Aristeomorpha foliacea* (Risso, 1827), and *Penaeus kerathurus* (Forskål, 1775).

2. Decapod and Stomatopod Crustaceans in Turkish Seas

Up to date, a total of 254 decapod and 8 stomatopod crustaceans were reported from the Turkish coast. In last two years, 6 of a total of 254 species were reported as new record (Bakır *et al*., 2014).

Despite of there are no comprehensive surveys carried out to cover all the Turkish coast as regards deceapod and stomatopod crustaceans of the Turkish shores, knowledge that is considered to be sufficient was achieved in last 50 years. This information was based relevant scientific works, mainly Kocatas (1971), Kocataş *et al*. (1991), Kocatas and Katagan (2003), Ateş (2003), Bakır *et al*. (2014).

3. Commercial Species in the Turkish waters of the Aegean Sea

Doğan *et al*. (2007), reported a total of 13 decapod crustacean species with commercial value for Turkish Aegean Sea. Yet, the number of decapod and stomatopod crustaceans known from the Turkish shores of Aegean Sea is 19 (Table 1).

3.1. Shrimp fisheries

P. longirostris, *A. foliacea, A. antennatus*, and other pandalid shrimps are the most important species for commercial fisheries in our seas. Shrimp fisheries using beam trawl is made in Turkish Seas. Deep water rose shrimps are fished by means of otter trawls, especially in the Mediterranean. The total catch of shrimp amounted to 3856 tonnes in 2006 (Anonymous, 2007), most of which was caught in the Sea of Marmara (62%). The pink shrimp, *P. longirostris* comprises dense populations in the Sea of Marmara. Other commercial shrimp species in Turkish seas are penaeid shrimps suc as; *A. foliacea*; *Metapenaeus stebbingi* (Nobili, 1904); *Penaeus pulchricaudatus* Stebbing, 1914; *Penaeus semisulcatus* de Haan, 1844 and *P. kerathurus*. The fishing amounts on the Turkish coast between 2009 and 2013 are 4614,0; 4 705,0; 4 769,9; 5 038,1 ve 4 027,6 tones, respectively. Shrimp fishing was the highest level in 2005, whereas, this level decreases from year to year (TUİK, 2013).

3.2. Penaeid shrimps

Penaeid shrimps have a considerable importantance in both fiheries and aquaculture production due to their economic value. 8 species [*Metapeaeus monoceros* (Fabricius, 1798); *Metapenaeopsis aegyptia* Galil & Golani, 1990; *Metapenaeopsis moigensis consobrina* (Nobili, 1904); *M. stebbingi*; *P. pulchricaudatus*; *P. semisulcatus*; *Penaeus hathor* (Burkenroad, 1959), and *Trachysalambria curvirostris* (Stimpson, 1860)] of alien penaeid shrimps appear on the Mediterranean Sea coast of Turkey (Özcan *et al*., 2006). Only seven species of penaeid shrimps (*M. monoceros*, *M.*

stebbingi, *P. semisulcatus*, *P. pulchricaudatus*, *P kerathurus*, *P. longirostris* and *T. curvirostris*) were stated to be commercially important for Turkish fisheries. Because of the population of *P. hathor* in the Turkish Aegean Sea is low, there is no detailed data on its present manner economically. Between the years 1956-1960 annual amount of penaeid shrimps, *A. foliacea*, *A. antennatus*, and *P. longirostrsis* caught from the Aegean Sea coast of Turkey was 12.6, 10, 21.0, 7.0 and 12.0 tonnes, respectively (Artüz, 1967). According to data of 2013, a total of 451 tonnes of green tiger prawn, 8.4 tonnes caramote prawn, 1619 tonnes pink shrimp, and 237,9 tonnes speckled shrimp was fished (TUİK, 2013).

Table 1. Decapod and Stomatopod crustaceans with commercially importance on Turkish Aegean Sea coast.

Dendrobranchiata
Aristaeomorpha foliacea (Risso, 1827)
Aristaeomorpha foliacea (Risso, 1827)
Metapenaeus affinis (H. Milne Edwards, 1837)
Parapenaeus longirostris (Lucas, 1846)
Penaeus hathor (Burkenroad, 1959)
Penaeus kerathurus (Forskål, 1775)
Caridea
Plesionika edwardsii (Brandt, 1851)
Plesionika heterocarpus (A. Costa, 1871)
Plesionika martia (A. Milne-Edwards, 1883)
Plesionika narval (Fabricius, 1787)
Macrura Reptantia
Homarus gammarus (Linnaeus, 1758)
Nephrops norvegicus (Linnaeus, 1758)
Palinurus elephas (Fabricius, 1787)
Scyllarides latus (Latreille, 1803)
Brachyura
Callinectes sapidus Rathbun, 1896
Carcinus aestuarii Nardo, 1847
Maja squinado (Herbst, 1788)
Portunus segnis (Forskål, 1775)
Stomatopada
Squilla mantis (Linnaeus, 1758)

3.2.1. *Aristaeomorpha foliacea* (Risso, 1827)

The giant red shrimp, *A. foliacea* is a demersal, deep-sea species with one of the widest geographical ranges known. *A. foliacea* is a dominant species in Mediterranean Sea megafaunal assemblages, mainly occupying the middle slope between 450 and 600 m (Cartes *et al*., 2014). The comparative importance of *A. foliacea* and *A. antennatus* in deep-water fisheries alters for the west and east parts of the Mediterranean. Furthermore, knowledge limited is known as regards *A. antennatus* in the Mediterranean Ecosystem (Kapiris *et al*., 1998). Yet, *A. foliacea* was rarely reported in the Aegean Sea of Turkey (Özcan *et al*., 2009). As per data of 2013 red shrimps, *A. foliacea* and *A. antennatus* were presented together. A total of 363.6 tonnes for the Sea of Marmara Sea, 828.7 tonnes for the Aegean Sea, and 370.3 164.6 tonnes for the Mediterranean Sea were fished (TUİK, 2013).

3.2.2. *Aristeus antennatus* (Risso, 1816)

Red shrimp, *A. antennatus*, is the most important decapod in landed weights fished by the trawlers in the western Mediterranean Sea. Its price is usually one of the highest amongst crustaceans. The red shrimp is a high value species at market reaching peaks of 200 €/kg during particular periods such as Christmas or summer holidays (Gorelli *et al*., 2014). Red shrimp, *A. antennatus* was reported at depths of between 550 m and 670 m by means of a trawl on the Marmaris coast (the Turkish Aegean Sea) (Özcan *et al*., 2009).

3.2.3. *Metapenaeus affinis* (H. Milne Edwards, 1837)

Metapenaeus affinis (H. Milne Edwards, 1837) is distributed in the Indo-West Pacific, Indonesia, China, the Philippines, New Guinea, Arabian Sea. Its adults prefer sandy-muddy and muddy areas. *M. affinis* has a great commercial importance and it is cultured in the Philippines and it is commercially valuable in several Asian countries. This species is caught by trawlers and trammel nets. *M. affinis* is for the first time reported from İzmir Bay (the eastern Aegean Sea) for Turkish Seas (Aydın *et al*., 2009). Due to this species has a commercial importance continuously growing, it have been commonly hunted by fishermen in regions where it is found (Dinçer and Aydın, 2014). Amount of the avarege catch for M. affinis was 18, 26, 12 kg in spring, summer, and autumn of 2008 respectively, and 10, 15.3 kg respectively in 2009 (Aydın and Metin, 2010).

3.2.4. *Parapenaeus longirostris* (Lucas, 1846)

Shrimp fisheries in Turkey has been carried out since the beginning of 1980's and total product reached to 8380 tonnes in 1989. But, a significant decline in shrimp fisheries was observed at the last 10 years and total production decreased to 890 tonnes in 1990. Approximately 72% of shrimp harvest on Turkish coast was obtained by the stocks of the Sea of Marmara (Zengin *et al*., 2004). These stocks are composed of mostly pink shrimp, *P. longirostris*. According to data of 2013, totally 1619.9 tonnes (for the Sea of Marmara 1209.1, the Aegean Sea 344.7, and the Mediterranean Sea 66.1) were fished (TUİK, 2013). *P. longirostris* is actually the target species of an important fishery and commercially caught by bottom trawls on the Turkish coasts of Turkey. Despite of *P. longirostris* has dense populations in the Turkish Aegean Sea, we can see several studies on its population and biology. Recently, Bilgin *et al*. (2012) carried out a study detailed on the bathymetric distribution and population of *P. longirostris* in Saros Bay. According to same authors, a total of 2347.4 kg with approximately 254975 specimens of *P. longirostris* was recorded from the depths between 20 and 463 m of Saros Bay (the northeastern Aegean Sea).

3.2.5. *Penaeus kerathurus* (Forskål, 1775)

The prawn *P. kerathurus* appears on muddy or muddy-sand bottoms of marine and brackish waters environments. *P. kerathurus* is found at the depth ranges from 0.5 to 90 m, but mainly up to 40 m. Its geographical distribution range is limited to the eastern Atlantic coasts from the northern Angola to the southern England, and the Mediterranean. *P. kerathurus* has a considerable importance for commercial fishery in the Mediterranean Ecosystem. Due to competition with other exotic shrimps (especially penaeids) penetrated to the eastern Mediterranean by Suez Canal, it almost disappeared on Israel, Syria, and Turkey coast. Native habitat of *P. kerathurus* was extinguished mainly by other penaid shrimp, *P. pulchricaudatus* (as *Marsupenaeus japonicus*) (Kevrekidis and Thessalou-Legaki, 2011).

Target species for the Aegean Sea coats of Turkey is cramote prawn, *P. kerathurus*, and this species is captured commonly in Izmir Bay. Approximately, 273.000 kg year^{-1} of *P. kerathurus* was caught from İzmir Bay between 1985 and 1987. This amount was expected to decrease to 136.000 kg year^{-1} in 1991 (Hoşsucu, 1990).

3.3. Pandalid shrimps

Four species of genus, *Plesionika* occur along the continental shelf and slope of the Turkish Aegean Sea coast. Notwithstanding, despite their widespread occurrence in demersal fisheries research samples, there is no study on aspects of their biology and ecology in the Turkish Aegean Sea waters. *Plesionika martia* (A. Milne-Edwards, 1883) and *Plesionika heterocarpus* (A.Costa, 1871) are the most dense species of pandalid shrimps in the Mediterranean (Koçak *et al*., 2012). Pandalid shrimp and other decapods of Sigacik Bay (Aegean Sea) were mostly dominant in the depth zone of 300-400 m. Pandalids such as *Plesionika narval* (Fabricius, 1787) and *P. heterocarpus* in some areas of the Aegean Sea coast ot Turkey are known as discard species (Özcan and Katağan, 2009). On the other hand, *P. heterocarpus* is known as commercially important with *P. longirostris* in some regions (Akçınar *et al*., 2007).

3.3.1. *Plesionika heterocarpus* (A.Costa, 1871)

P. heterocarpus have a distribution restricted to the Mediterranean Sea and the Eastern Atlantic both in temperate and tropical waters (Holthuis, 1980). This species usually occur at depths from 300m to 600m. (Özcan and Katağan, 2009). In the Sigacik and Kusadasi Bays mainline of fishing efforts was directed to shrimps, which are *P. longirostris*, *P. heterocarpus*, *Aegaeon lacazei* (Gourret, 1887) and *Pasiphaea sivado* (Risso, 1816) (Akçınar *et al*., 2007).

3.3.2. *Plesionika martia* (A. Milne-Edwards, 1883)

Golden shrimp, *P. martia* is distributed both in temperate and tropical waters (Holthuis, 1980). This species appears in all waters of the Mediterranean at the depths of 165-871 m and is caught by commercial deepwater trawls (Koçak *et al*., 2012). A total of 13.44 kg of shrimps was daily captured during trawl surveys (52 hauls) carried out on the eastern Mediterranean coast of Turkey. This amount comprises 5% of commercial product obtained from the area (Demirci, 2007).

3.3.3. *Plesionika narval* (Fabricius, 1787)

Narval shrimp, *P. narval* is a cosmopolitan species (Figure 1). This species is distributed in the eastern Atlantic Ocean, the Mediterranean Sea, the Red Sea and Indo-West Pacific from Madagascar to French Polynesia (Sousa *et al*., 2014). Pandalid shrimp, *P. narval* isn't known as a commercial species in the several areas of the Turkish Aegean Sea (Özcan and Katağan, 2009). *P. narval* is not fished commonly in the Turkish Aegean Sea.

Figure 1. Narvalshrimp, *Plesionika narval* (Fabricius, 1787) (Photo by T. Özcan)

3.4. Lobsters

3.4.1. *Homarus gammarus* (Linnaeus, 1758)

The European lobster, *Homarus gammarus* (Linnaeus, 1758) was reported from the Mediterranean Sea, the Black Sea, and the Bosporus. This species is usually found between sublittoral waters and the depths until 150 m. The common lobster, *H. gammarus* which is commercially valuable is captured by means of old trammel and gill nets (Ayaz, 2003). Data of 2013 show that in total 7.0 tonnes of lobsters (for the Sea of Marmara 0.5 and the Aegean Sea 6.5) were fished (TUİK, 2013).

3.4.2. *Nephrops norvegicus* (Linnaeus, 1758)

Norway lobster, *N. norvegicus* is a target species for commercial fisheries activities that are being carried out in the Mediterranean (Figure 2). Norway lobster, *N. norvegicus* is the second crustacean in volume of catches after red shrimp (Carbonell *et al*., 1999).

Figure 2. Norway lobster, *Nephrops norvegicus* (Linnaeues, 1758) (Photo by T. Özcan).

Norway lobster, *N. norvegicus* in the Mediterranean is captured by the general techniques of trawl fisheries. Fishing methods used on *N. norvegicus* fishery in the Mediterranean differ actually (Sardà, 1998). Highest biomass of *N. norvegicus* in Saros Bay (the northeastern Aegean Sea) was recorded as 433.22 (kg m^{-2}) for Spring time (İşmen *et al*., 2013). Estimated biomass of the species is 1450 tonnes and it is dense at the depths of 200-250 m (Benli *et al*., 2000). *N. norvegicus* is considered commercial important species (Özcan and Katağan, 2009). A total of 5.7 tonnes of Norway Lobster was captured in the Turkish Aegean Sea (TUİK, 2013).

3.4.3. *Palinurus elephas* (Fabricius, 1787)

Spiny lobster, *Palinurus elephas* is a large lobster species occurring in temperate waters of the northeastern Atlantic and is also found in all the Mediterranean Sea

(Figure 3). The species recorded as vulnerable (VU) status in IUCN Red List in 2015 (Goňi, 2014). *P. elephas*' fisheries is quite remarkable socio-economically in the western Mediterranean. Before the species was fished by baited traps, but nowadays it is captured by means of trammel nets. With the replacement of traps by trammel nets, fishing effort on *P. elephas* has increased fuelled by the growing tourist market around the Mediterranean coast and its high unit price (40–50 euros·kg-1 first sale) (Quetglas *et al*., 2004). According to 2013' data, 11.5 tonnes in total was fished and approximately 94% of this amount was obtained from the Aegean Sea (TUİK, 2013). It is reported to live in special environmental protection area in Gokova Bay (the eastern Aegean Sea) (Ayaz *et al*., 2010), on the Imbros coast of the northeastern Aegean Sea (Gönülal, 2012), and in the Bosporus (Balkıs *et al*., 2002).

Figure 3. Spiny lobster, *Palinurus elephas* (Fabricius, 1787) (Photo by T. Özcan).

3.4.4. *Scyllarides latus* (Latreille, 1803)

According to Butler *et al*. (2013) this species is still quite common in the eastern Mediterranean along the coasts of Israel, Cyprus, Greece, Turkey and along the North African coast.

3.5. Losbter fishing in Turkish waters

The Turkish fishery regulation circular (TFRC) arrange the prohibitions for lobster fishing. Spiny lobster, *P. elephas* and other lobster species in the northern Aegean Sea for two months (between 15, April and 15, June) of every year are fished. Fisheries of spiny lobsters and other lobster species is carried out between Saros Bay and Babakale coast (Imbros) at the depths of 50-150 m. Besides, *P. elephas* specimens are captured on the coast of Foça (the eastern Aegean Sea) (Gönülal, 2012).

3.6. Portunid crabs

Among the brachyuran crabs, portunid crabs is one of the better documented taxonomic groups. Portunid crabs are economically valuable and among these, blue crab, *Callinectes sapidus* Rathbun, 1896 and *Portunus segnis* (Forskål, 1775) are found in the Turkish waters (Özcan, 2012). These two species are exotic species in the Mediterranean Sea. The amount of blue crab, *C. sapidus* fished from the Turkish coast is roughly 48 tonnes between 2006 and 2012 (TÜİK, 2013). Most probably, this amount contains data belong to swimming crab, *P. segnis*' fishing (TUİK, 2013). Fishing of the blue crab, *C. sapidus* in lagoon areas around the Dardanelles is performed in summer period and the amount fished is around 1 ton daily (Pers. comm. by T. Özcan).

3.6.1. *Callinectes sapidus* (Rathbun, 1896)

Blue crab, *C. sapidus* was reported from the western Atlantic, from Nova Scotia to Uruguay, European Atlantic coast, Baltic Sea, Mediterranean and Black Sea (Özcan, 2003). Blue crabs can tolerate the environmental variables with a wide range. They live in different habitats of hipersalin lagoons with the salinity from the freshwater to 117 ppt (Williams, 1984). Their tolarance to environmental temperature is too high (<3ºC to >35ºC) (Tankersely and Forward, 2007).

The amount of blue crab, *C. sapidus* caught from the Levantine Sea coast of Turkey in 2009 is around 77 tonnes (Özcan, 2012). Specimens of blue crab are mostly caught by crab traps that are a rectangular.

3.6.2. *Portunus* (*Portunus*) *segnis* (Forskål, 1775)

P. segnis consumed as human food is distributed in Indo-West Pacific from Pakistan to the south Africa and the Mediterranean (Lai *et al*., 2010) (Figure 4). *P. segnis* is known as a Lessepsian species occurrs on the coast of Egypt, Palestinian, Syria, Cyprus, the Levantine of Turkey, Greece, and Italy (Özcan, 2012). As the results of findings of the revision study performed in 2010, the species was renamed as P. segnis, instead of *P. pelagicus* (Lai *et al*., 2010).

This species known from the İskenderun Bay is named with names such as blue and spotted. *P. segnis* is sold from one Turkish Liras for one in fishing markets 20% of the crab specimens captured is evaluated economically and remainder is excreted (Özcan, 2003).

3.7. Stomatopod Fisheries

Stomatopod species are a neglected fishery resource among the crustaceans. Stomatopod species by-catches of demersal fish and decapod crustacean fisheries can be of potential fishery interest. Stomatopod fisheries in the Mediterranean is focused in target mantis shrimps inhabiting the muddy or sandy bottoms of the shallow waters (shallower than 80-90 m) (Vaupel Klein *et al.* 2013).

Figure 4. Blue swimming crab, *Portunus segnis* (Forskål, 1775) (Photo by T. Özcan).

3.7.1. *Squilla mantis* (Linnaeus, 1758)

The spottail mantis shrimp, *Squilla mantis* (L., 1758) is distributed in all the Mediterranean Sea (Figure 5). This stomatopod species comprises the high densities on the bottoms with fine sand and sandy mud. *S. mantis* has commercially exploited primarily on the Mediterranean coasts of Italy, Spain, and, to a lesser extent, France, Egypt, and Israel. *S. mantis* is consumed as human food (Lakshmi Pillai and Thirumilu 2012). Among stomatopod species in the Mediterranean, *S. mantis* has economic value, however, Lessepsian migrant, *Erugosquilla massavensis* (Kossmann, 1880) is captured commercially in the Levantine basin of the Mediterranean (Holthuis 1987). *S. mantis* is known to be an important predator of some fish, crustacean, and cephalopod species (Vaupel Klein *et al.* 2013). This species is found on all Turkish coast excluding the Black Sea shores (Bakır *et al.* 2014).

Figure 5. Mantis shrimp, *Squilla mantis* (Linnaeus, 1758) (Photo by T.Özcan).

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AEGEAN SEA ICHTHYOFAUNA

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1. Introduction

The term "biodiversity hotspot" was formed to serve as a key contribution to conservation strategies, indicating particular areas that feature exceptional concentrations of species with high level of endemism and face exceptional threats of destruction (Myers, 1990). Except for a few localities, almost the entire Mediterranean basin (including Aegean Sea) was defined as a biodiversity hotspot (Myers *et al*., 2000), indicating the need for more detailed research in the region. Recent scientific works dealing with benthic habitats have already promoted Aegean Sea as a priority area for conservation (Giakoumi *et al*., 2013), and a relevant approach from the view point of fish faunal assemblages are yet to be carried out.

Observations on Aegean Sea fishes are available since the prehistoric times, but the overall picture we achieved today on the general structure of the ichthyofauna is based on very recent studies made (for full account see Bilecenoglu *et al*., 2014), especially during the last few decades. Majority of the available research are formed of case studies (i.e. range expansion records) and a few large scale inventories financed by the government occur (such as the ichthyofaunas of Datça peninsula and Gökova Bay specially protected areas).

The main purpose of this review is to summarize the general ecological structure of the marine fish fauna of Aegean Sea (Turkish coasts) and to characterize its species composition. Since relevant checklists are available, no species lists will be presented herein.

2. Brief History of Ichthyological Studies

Archaeozoological evidence indicates that the exploitation of marine fishes date back to Mesolithic period (ca. 10000 BC), in which the Aegean Sea shores were culturally populated sparsely by communities of hunters, gatherers and fishermen (Mylona, 2014). In several ancient coastal cities of the Aegean Sea (i.e. Troy, Ephesus, etc.), remains of fishing implements (such as fishing hooks made of bone) were recovered during excavations together with many fish skeletons, demonstrating the importance of fishes in the communities diet even several millennia ago (Neer and Uerpmann, 1998; Bursa, 2007). What was actually chosen to be caught by ancient

Aegean fishermen or consumed by people is cleary revealed by archaeology, and to a lesser extend by written sources and artistic expressions - where it seems the fishermen do not principally monitor the abundance of fishes, but the part of it that was accessible and exploitable in specific locations (Mylona, 2015). Such an attitude essentially requires a perspective of "ecological analysis", i.e. observations on habitat preferences of all coastal commercial fish species. This certainly means that the prehistoric fishermen, hunters and gatherers were sorts of ancient ichthyologists, who learned in time how, when and where to capture fishes. Nevertheless, Aristotle (384 – 322 BC) would be the first person to be crowned as the father of zoology and ichthyology, attributing to the scientific methodology he followed. Aristotle's observations on fishes were almost exclusively carried out at the Aegean Sea (including some coasts currently located in modern Turkey), but only a few authors in the following epoch mentioned about fishes of the region, i.e. Athenaeus (AD 3rd century). Ichthyological research hibernated for the following 15 centuries, where the French zoologist, botanist and diplomat Pierre Belon (1517-1564) was the pioneering researcher providing information on fish and fisheries of the Ottoman Empire. Belon travelled to several Anatolian cities and published a series of natural history books, which included descriptions of a few but common commercial fish species from the Aegean Sea. In the late 18^{th} century, two of the Linnaeus’s disciples (Hasselquist, 1757; Forsskål, 1775) carried out ichthyological surveys partly in İzmir. Species those listed by Forsskål (1775) represent the first post-Linnaean fish inventory of Turkish Aegean Sea shores, followed by studies of Cuvier and Valenciennes (1836) and Carus (1893). Most notable research during the early 20th century was conducted by Fage (1918) and Ninni (1923). The number of recorded species from the eastern Aegean Sea was 90 until the 1950's, which thereafter increased especially by the detailed work of Geldiay (1969) (Figure 1). In the following decades, two monumental studies largely shaped the faunal structure (Whitehead *et al*., 1984-1986; Fischer *et al*., 1987), adding 63 and 21 previously unrecorded species from the Turkish Aegean coasts, respectively. Later faunistic works concentrated on either deep sea fish or the range expansion records of alien species, bringing up the total number of recorded fish to 389 by the early 2000's (Bilecenoglu *et al*., 2002). It is striking to note that, the Aegean Sea coasts of Turkey are currently represented by 448 fish species (Bilecenoglu *et al*., 2014), 51 of which were recorded only during the last decade.

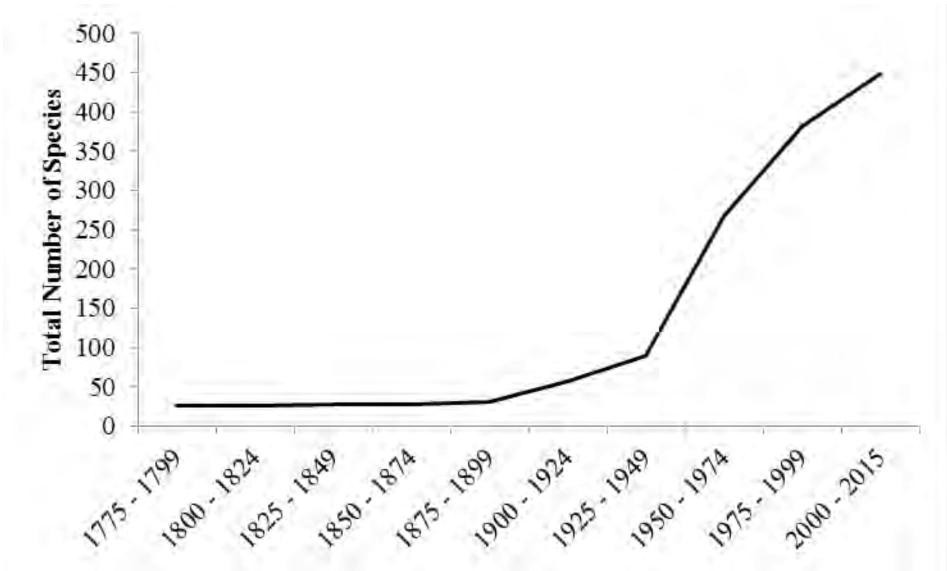

Figure 1. Cumulative increase in number of fishes recorded from the Aegean Sea.

3. Characterization of the Fish Fauna

Aegean Sea is a transition area between the Mediterranean itself and the Black Sea, which maybe divided into several subsections depending on the criteria chosen. The GFCM considers Aegean Sea as a single fishery division and a management unit, while Papaconstantinou (1988) mentions of two subregions (north and south) and Tokaç *et al*. (2010) prefers the use of three subregions (north, central and south). Whatever the criteria preferred, there are at least two distinct basins from the zoogeographical viewpoint, where boreal and Pontic forms concentrate at the northern Aegean (such as *Sprattus sprattus*, *Merlangius merlangus*, *Neogobius melanostomus*, etc.) and thermophilic/subtropical forms at the southern Aegean Sea.

The ichthyofauna of eastern Aegean Sea comprises 448 species belonging to 139 families, comprising an average of 3.2 species per family. This average is similar to that of the Sea of Marmara and the Levant, but departs from the Black Sea that had a different zoogeographical history (Bilecenoglu and Taşkavak 1999).

An analysis of the distribution of fish species among families revealed that, only 10 had 10 or more species (with Gobiidae being the most specious one), and 22 families include 5 or more species (Table 1). From the rest 117 families, majority are monospecific (67 families), while 23 families are represented by 2 species, 14 families by 3, and 13 families by 4 species.

Table 1. List of families represented by more than five species.

Family	Number of Sp.	Family	Number of Sp.
Gobiidae	36	Triglidae	8
Sparidae	25	Mugilidae	8
Labridae	20	Gobiesocidae	7
Blenniidae	18	Callionymidae	7
Rajidae	13	Clupeidae	6
Carangidae	13	Scorpaenidae	6
Myctophidae	12	Bothidae	6
Soleidae	11	Tetraodontidae	6
Serranidae	10	Ophichthidae	5
Scombridae	10	Macrouridae	5
Syngnathidae	8	Scopthalmidae	5

The habitat preferences of Aegean Sea fish were examined under 7 categories, following Fishbase definitions (Froese and Pauly 2015): 1) benthopelagic (living and feeding near the bottom as well as in midwaters or near the surface), 2) bathypelagic (living or feeding in open waters at depths between 1,000 and 4,000 m), 3) bathydemersal (living and feeding on the bottom below 200 m), 4) demersal (living on or near the bottom and feeding on benthic organisms), 5) pelagic-neritic (the shallow pelagic zone), 6) pelagic-oceanic (offshore pelagic zone), and 7) reef associated. The benthic/demersal domain outnumbers the pelagic zone, similar to the phenomenon observed in other seas surrounding Turkey. Each habitat includes representatives of typical families; for example Ipnopidae, Dalatiidae, Epigonidae and Hexanchidae includes bathydemersal species, while Myctophidae, Stomiidae and Phosichthyidae includes bathypelagic species.

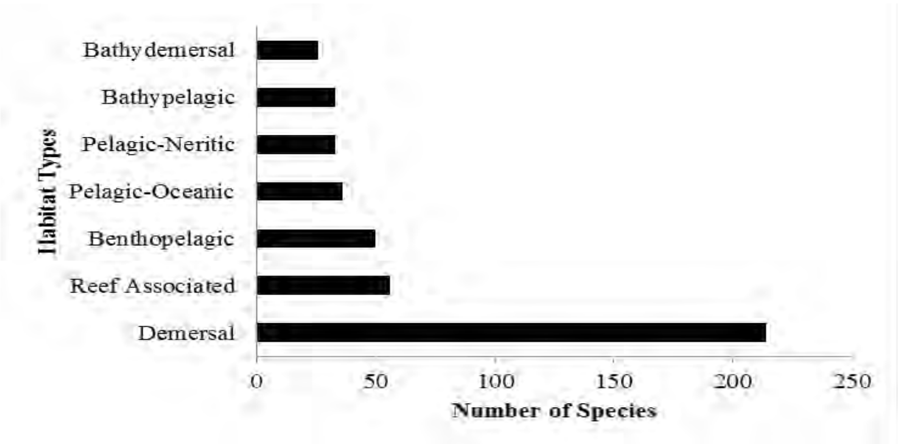

Figure 2. Habitat preferences of Aegean Sea fish.

Trophic levels express where the fish and other organisms tend to operate in their respective food webs. A primary consumer (herbivores) have values between 2.0 and 2.19, while secondary consumers (carnivores) may have trophic levels equal to or greater than 2.8 (Froese and Pauly 2015). The mean trophic level of the Aegean Sea ichthyofauna is 3.61, with herbivorous species like *Sarpa salpa* and *Coryphoblennius galerita* were located at the lowest level (=2) and the hammerhead shark *Sphyrna zygaena* (=4.9) being placed as the apex predator. Mean trophic levels (and their ranges) of specious families are presented in Figure 3.

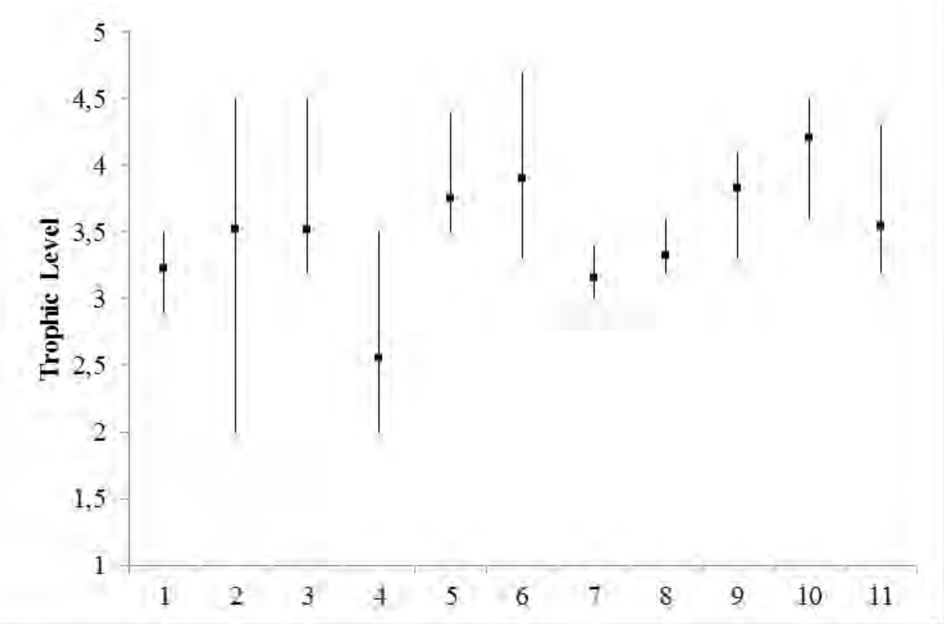

Figure 3. Mean trophic levels (MTL) of species rich families. 1) Gobiidae (3.23), 2) Sparidae (3.52), 3) Labridae (3.51), 4) Blenniidae (2.55), 5) Rajiidae (3.75), 6) Carangidae (3.90), 7) Myctophidae (3.16), 8) Soleidae (3.32), 9) Serranidae (3.83), 10) Scombridae (4.21), 11) Syngnathidae (3.54).

At biogeographical level, Mediterranean Sea biota includes 55-77% of Atlantic species, 3-10% of cosmopolitan species, between 20 and 30% of endemics, and a considerably proportion of alien species whose percentage is higher at the eastern basin (Bazairi *et al*., 2010). According to the recent estimates from the Aegean Sea, 62.7% of the fish are of Atlanto-Mediterranean origin, followed by species endemic to the Mediterranean Sea (15.2%), cosmopolitan species (13.2%) and alien species (8.9%). Since the rate of alien species introductions have a tendency to increase, their proportion in a particular ecosystem also changes swiftly. A total of 28 alien fish were previously compiled from the Aegean Sea (mostly concentrated at the southern sections) (Bilecenoglu, 2010), which has now increased at least by 10 species. Among the newcomers that has recently been recorded from the Aegean coasts, *Torquigener flavimaculosus* and *Nemipterus randalli* can be given as examples (Figure 4) - the latter species now gives catch in high quantities especially at Marmaris, Datça and Gökova coasts.

Maximum total lengths of Aegean Sea fish range from ca. 3.0 cm to 1000 cm. Several cryptobenthic fish families typical to very shallow shores (such as Gobiidae, Gobiesocidae, Blenniidae, etc) and a few true deep water taxa (i.e. Phosichthyidae, Gonostomatidae and Sternoptychidae) includes species with total lengths smaller than 5 cm. In general, 13.8% of the ichthyofauna is composed of small sized fish (< 10 cm total length), while the rest are either medium sized (10 - 50 cm, 42.2%) or large sized species (>50 cm, 43.9%). Fishbase gives a maximum length of 11 m for *Regalecus glesne*, but considering actual observations, the single *Cetorhinus maximus* individual (with ca. 10 m total length) captured off Çanakkale coasts seems to hold the record at least for the Turkish coastline (see Kabasakal, 2013 for specimens details).

Musick (1999) has suggested values for several biological parameters that allow to classify a fish population or species into categories of high, medium, low and very low resilience or productivity. For example, a long lived and slow growing fish (let us assume Carcharodon carcharias) maturing at an age >10 years with low fecundity (<10/year) would have a "very low resilience" to fishing pressure. Likewise, fast growing, early maturing and highly fecund fishes will have high productivity values and therefore likely to tolerate fishing pressures. An analysis of the Aegean Sea fishes showed that (based on data presented by Fishbase), there are 123 species with "very low" or "low" resilience scores, indicating 27.5% of the existing fauna requires special concern and should immediately be managed.

4. Remarks

Considering all seas surrounding Turkey, Aegean Sea is the most prominent one due to its high fish diversity. Most components of the relevant fauna has just been discovered and several more are waiting to be explored. Although 448 species were recorded within 240 years (since Forsskål, 1775) - equivalent to almost 2 new species records per year, rate of fish taxonomists recruited in the universities are strikingly low - maybe as low as 1 scientist in every 20 years. Finance is topmost importance in nearly all branches of marine biology, but without the presence of a researcher who devoted himself to ichthyology, progress in that field would be a sweat dream.

Figure 4. Two alien fish recently introduced to the Aegean Sea - *Torquigener flavimaculosus* (up), *Nemipterus randalli* (bottom) (Photos: M.Bilecenoğlu)

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BIRDS OF THE AEGEAN SEA

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1. Introduction

Birds are found to be almost everywhere, from the south pole to the north, from sea level to the highest mountain, from deserts to the most crowded cities, from a little puddle to the middle of the widest ocean, from the largest arable land to the densest forests. They are both beautiful and colourful. They have large varieties in sizes, from the smallest Bee Hummingbird (*Mellisuga helenae,* which measure 57 mm in total length) to the largest living North African Ostrich (*Struthio camelus*, which measure 2.8 m in length). Birds are observable at many times from closer distances unlike many other animals. Most of the bird species can easily be domesticated for many purposes, for example for egg and meet production, for their beautiful songs, for even hunting the other animals. Besides these, Bird's ability of flight has fascinated humans much more than any other flying animals - such as insects, bats of some gliding mammals- as none of these animals can demonstrate similar skills flying. Birds have always drawn the attention of mankind throughout the history. Evidences can be found on numerous numbers of different materials, goods and or in cultures, such as from Stone Age cave paintings through the sacred ibises of ancient Egypt civilization, and the symbol of wisdom of owls of Hellenistic times and to respected eagles of the totems of the American Natives (Flegg, 1984). Even in modern world, one can see too many concepts in our everyday life to be expressed by the life of birds, such as, freedom, beauty, peace, and power.

2. The Aegean Sea

The Aegean Sea is located between the Greek and Anatolian peninsulas, i.e., between the mainlands of Greece and Turkey (Figure 1). In the northeast, the Aegean Sea is connected to the Marmara Sea and Black Sea by the Dardanelles and Bosporus. Crete, Rhodes and Kithira Islands bound the Aegean Sea on its southern periphery. In geographic terms, the Aegean Sea is actually an elongated embayment of the Mediterranean Sea. Due to -like many other examples in the word- its partially closed geographical structure, it has become tradition to be called as another sea. However, Aegean Sea – with the same reasons can be divided in to three different parts: The North Aegean Sea, The South Aegean Sea and the Sea of Crete (Figure 1).

The Aegean Sea has long been a crossroad of cultures. There are hundreds of islands and thousands of islets and rocks throughout the Aegean Archipelago. Besides, the Aegean Sea is almost completely surrounded by mainlands and islands and forms a unique structure for both to civilizations and to the living creatures.

The word archipelago was originally applied specifically to the Aegean Sea and its islands. Many of the Aegean Islands, or chains of islands, are actually extensions of the mountains on the mainland (Wikipedia, 2015). One chain extends from Argolikos to Crete through Kithira Island, which is called Peloponsinos - Cretan ridge. Another chain extends from the Crete Island to the Datça Peninsula through Kassos, Karpathos and Rhodes islands, which is called Cretan - Rhodes ridge. These two Cretan-connected ridges actually divide the Aegean Sea from the Mediterranean Sea. Besides these two ridges explained there extend a third ridge, which extends from Dilek Peninsula and reaches to Euboea (Evia), through Samos, Ikaria, Mikonos, Tinos, and Andros İslands, which divides the Aegean Basin into two Parts as Northern Aegean Sea and Southern Aegean Sea. The climatic characteristics and the temperature ranges of the North Aegean and the Southern Aegean differ substantially (Skliris *et al***.** 2011).

Figure 1. The main geographical, topographical and bathymetrical features of the Aegean Sea Region. Only larger islands and key geographical features are included. (Original)

3. Birds of the Aegean Sea

Aegean Sea is the home of about 360 bird species, some of which occur exclusively in this climatic zone share these birds together with the rest of the Mediterranean Sea. Among those birds are sea birds, waterbirds, raptors and Passerines.

Similarly, to the climatic differences between the Southern and the Northern Aegean, the bird species compositions in these two sub-regions of the Aegean Sea show significant differences. In open words; the Northern Aegean Sea is sheltering about 350 species, while the Southern is only about 300 species according to various International Bird Database such as Avibase (http://avibase.bsc-eoc.org) and Kusbank (www.kusbank.org). Nevertheless, this difference does not mean that the Northern Aegean is more important in terms of biological conservation than the Southern Aegean. Actually, each region holds significant populations of many Endangered and Threatened birds species. The main difference between these two numbers is due to fact that most wintering bird species prefer to overwinter in the wetlands located at the Northern Aegean. This is mainly because of the fact that the northern Aegean holds much more wetlands than the southern Aegean. Among the existing wetlands at the north, the larger ones are Evros/Meriç Delta (both in Greece and in Turkey), Gediz Delta (Izmir-Turkey), Büyük Menderes Delta (Aydın Turkey), Porto Lagos Lagoon (Xanti-Greece), Axios Delta (Thessaloniki-Greece).

3.1. Sea Birds

Sea birds or commonly called as pelagic bird species are relatively few in the Aegean Sea. These are Cory's Shearwater (*Calonectris diomedea*), Yelkouan Shearwater (*Puffinus yelkouan*), and European Storm-Petrel (*Hyrobates pelagicus*). Pelagic birds are found mainly on the rocky shores and or sea-cliffs on small and isolated rocky islands and islets.

3.2. Waterbirds

Waterbirds create the second largest bird group of the Aegean Sea. There are al least 137 Water birds species have been observed in the region. This group also includes coastal seabird shallow waterbird species such as terns and waders. They occur on river deltas, estuaries, lagoons, nearshore inland wetlands and out at sea. These birds are swans, geese, ducks, divers, pelicans, cormorants, flamingos, herons, egrets, gulls, terns and waders. Among the birds listed, Great white Pelican (*Pelecanus onocratalus*), Dalmatian Pelican (*Pelecanus crispus*), Greater Flamingo (*Phonenicopterus roseus*), Audouin's Gull (*Ichthyaetus (=Larus) audouinii*), and Yellow-legged Gull (*Larus michahellis*) forms the main important waterbirds species that can be seen in the region.

3.3. Raptors

In the Aegean Region there are least 35 different diurnal and seven different nocturnal raptor species have been observed and documented both during breeding, wintering and or during migration season. These raptors are found mainly on sea-cliffs and or high and rocky mountains. The most common diurnal raptors of the Aegean Region are Eleonora's Falcon (*Falco eleonorae*), Peregrine Falcon (*Falco peregrinus*), Lesser Kestrel (*Falco Naumanni*), Bonelli's Eagle (*Hieraaetus fasciatus*), Short-toed Snake Eagle (*Circaetus gallicus*), Griffon Vulture (*Gyps fulvus*), and Long-legged Buzzard (*Buteo rufinus*). While the most common nocturnal raptors are Little Owl (*Athene noctua*), Eurasian eagle-owl (*Bubo bubo*). Among the birds listed, there is only one bird which is totally emblematic to the Aegean Sea is Eleonora's Falcon. Eleonora's Falcon breeds in very large colonies reaching up to several hundreds pairs. This emblematic species starts breeding –unusual to the other raptors and birds- during the autumn migration season for they attack to migratory birds above the open sea and they feed their chicks with those birds. Almost 85% of the global population of this migratory Falcon nest in the Aegean Region (Papaconstantinou, 2007).

3.4. Passerines (Song Birds)

The largest group of birds in the Aegean Sea is song birds reaching up to about 150 bird species. Various habitats of the Aegean Sea, especially, Maquis, Garrique, and woodlands which is dominated mainly by Pine, Juniper and Oak trees, and even wetlands serve them suitable breeding and feeding locations. The list of Passerines species observed so far may be found in the checklist of Birds in the Aegean section.

3.5. Bird Migration in The Aegean

Every year a large number of western Palearctic birds leave their territories at the end of the breeding season and head for southern latitudes, towards their wintering areas often located in Africa. In spring they do the same journal in the opposite direction to reach their breeding territories in the North. During the migration season different birds use different strategies: Broad-winged large birds like birds of prey, storks, pelicans move mostly using soaring-gliding flight while the majority of other birds move using flapping flight (Papaconstantinou, 2007). Thus, during migration most of the soaring birds prefer to migrate over the land, While Passerines and other small birds select the flight altitude in order to find the best tailwind assistance more than soaring raptors (Mateos-Rodríguez & Liechti 2012). Besides, raptors migrate mostly during the day since they use existing thermals over land avoiding flying over water surfaces where they are forced to use powered flight.

Migration phenology of Birds over the Aegean Sea is relatively less known phenomenon as comparing with the other well-known migration routes (Panuccio *et al* 2013). To be able to understand the migration phenomena, it is necessary to understand the winds Aegean. The etesian winds (Meltemi winds) are generally northern winds coming from the Black Sea and The Sea of Marmara reaching up to the South Aegean Sea- Crete. These winds create a very large block of wind body covering the whole Aegean and starting from the sea surface reaching up to about 2000 m. These winds occur mainly in September and August (Papaconstantinou, 2007). During the autumn migration all the migratory birds uses this tail wind to reach their wintering ground much faster than the other birds preferring to migrate over the mainlands Greece and Turkey. On average the Meltemi winds help migrating birds to gain 5-10km/h speed and this fact allows those small land birds to easily from one island to the other in the Aegean Sea. Each year hundred thousands of small birds migrate over the Aegean Sea. As it is explained in the section of Raptors, It may be now clear to reader of this text why %85 of the Eleonora's Falcons -reaching up to 12,000 pairs only in the Aegean inhabit in this Region. The existence of those migratory birds is the only food resouse for those Eleonora's Falcons during the Autumn Migration (Papaconstantinou, 2007).

Besides the small land birds, The Meltemi winds of the Aegean Region helps many soaring raptors to migrate, especially medium-sized raptors. Among them the three commonest species are Eurasian Marsh Harrier (*Circus aeruginosus*), Western Honey Buzzard (*Pernis apivorus*) and the Short-toed Snake Eagle (*Circaetus gallicus*). These species fallow the similar pattern of the passerine species and move from one island to another or sometimes follow the coastline of Aegean either from Greek side or Anatolian side.

4. Endangered or Threatened Birds Species of the Aegean Sea

In 1995, the parties to the Barcelona Convention adopted a new protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean. Annex II of this protocol lists 15 bird species found in the Mediterranean as endangered or threatened bird species. Among those species 14 occur in the Aegean Region. These are Cory's Shearwater (*Calonectris diomedea*), Yelkouan Shearwater (Puffinus yelkouan), European Storm-petrel (*Hydrobates pelagicus* ssp. *melitensis*), European Shag (*Phalacrocorax aristotelis* ssp. *desmaresti*), Pygmy Cormorant (*Microcarbo (=Phalacrocorax) pygmaeus*), Great White Pelican (*Pelecanus onocratalus*), Dalmatian Pelican (*Pelecanus crispus*), Greater Flamingo (*Phonenicopterus roseus*), Osprey (*Pandion haliaetus*), Eleonora's Falcon (*Falco eleonorae),* Slender-billed Curlew (*Numenius tenuirostiris*) (If not extinct already), Audouin's Gull (*Ichthyaetus(=Larus) audouinii*), Sandwich Tern (*Thalasseus (=Sterna) sandvicensis*), and Litte Tern (*Sternula (=Sterna) albifrons*) (UNEP, 2003).

5. An Overview of the Threads for the Birds of the Aegean Region

An overview of the threads for the birds of Mediterranean is clearly been explained in the Barcelona Convention Protocol and in its annexes (UNEP, 2003). Not only bird species of the Aegean Region is similar to the Mediterranean Region but also the threads are similar. Therefore, we generally except and use the same information provided by the Protocol for the Aegean Region as well. Therefore, the species of Endangered or Threatened birds listed in the Protocol, are defined as the species:

- which are globally threatened;
- which are endemic to the region and have unfavourable conservation status;
- whose populations are not concentrated in the Mediterranean region but which have unfavourable conservation status in the region;
- whose populations are not concentrated in the Mediterranean region, have a healthy conservation status but regarded as flagship species;

However, they all have something in common. They are all endangered by a number of threats, including:

- Oil Pollution
- Direct and indirect depletion of food resources
- Non-sustainable forms tourism
- Disturbance
- Direct persecution (such as illegal hunting and use of posion)
- Mortality from by-catch
- Loss of Habitats
- Degradation of habitat, particularly wetlands and small islands of high biological importance for birds
- Introduction of and predation by alien species

6. The Key Habitats of the Aegean that serves as home for Birds

The Aegean Sea Region holds several different types of habitats. Some of them are important for birds and are explained as follows.

6.1. Spiny Mediterranean heaths: Maquis and Phrygana

According to the European Nature Information System (Eunis) habitat classification, Spiny Mediterranean heaths are described as the habitats of shrublands with dominant low spiny shrubs, widespread in the Aegean region with a summer-dry climate, occurring from sea level to high altitudes on dry mountains. Maquis are low evergreen shrub formation, usually found on siliceous soils in the Mediterranean and Aegean lands and islands where winter rainfall and summer drought are the characteristic climate features, while Phryganas are described horny formations of hemispherical shrubs of the coastal thermo-Mediterranean zone of Aegean islands, of mainland Greece and the Ionian islands, of coastal Anatolia and Crete (European Environment Agency, 2015). Literally Phrygana means the “vegetation of Phrygia”, a famous ancient civilization located at the southwest of Anatolia. These habitats serve as very important homeland for many bird species especially for Passerines.

6.2. Mountains and rocky islands and islets

There are hundreds of islands and thousands of islets and rocks throughout the Aegean Archipelago. Besides, the Aegean Sea is almost completely surrounded by mainlands and islands. The region holds several very high mountains such as Mt.Lefka-Ori (2,453 m), Mt Psiloritis/Ida (2,456 m) Mt. Dikti (2,148 m) in Crete, Mt. Bozdağ (2,137 m) in Turkey. Besides these mountains, almost all the islands and the coastline have high mountains with altitudes between 1000-2000 m, resulting in very steep hillside formations, cliffs and rocky shores. These mountains shelter not only numerous number of raptors but also passerines birds species.

Extensive rocky shores, islands and islets of the Aegean Sea provide many species to breed or roost. These species included are gulls, raptors, Pelagic (sea) birds and for some of duck species as well.

6.3. Rivers, Lakes, Lagoons and Marshes

The largest rivers of the Aegean Sea are Evros/Meriç river, Büyük and Küçük Menderes Rivers, Gediz River, Nestos River, Stirmon River, Axios, Loudias and Aliakmon Rivers. The Lagoon formations are mainly related by these river deltas. There are also much smaller lagoons located in the Aegaen islands. Lakes are not very abundant around the Aegean Sea, The Largest Lake is the Bafa Lake located at the west of Aydın, Turkey. The second largest one is the Porto Lagos Salty Lagoon located at the south of Xanti, Greece. Besides these there are numerous numbers of small freshwater lakes located in the inland and or on the islands. These habitats are important for many gulls, terns, waders, and duck species.

6.4. Woodlands

In the Aegean deciduous woodlands are scarce, but they offer rich and varied niches for a great number of bird species. These woodlands are mainly located at the northern side the Aegean Sea, where the temperature ranges are low and humidity and rainfall are high. May be the only exception to this rule is the Datça Peninsula Rodos island and its surroundings, where there are large regions covered by Oriental Sweetgum or Turkish Sweetgum Tree (liquidambar orientalis) grows. However, they can also be observed in some small locations such as, river walleys, canyons, facing to the North.

Coniferous woodlands, although supports less species is an habitat for many birds in the Aegean. Among them may be best known species of this habitat type is the Krueper's Nuthatch (*Sitta krueperi*).

6.5. Coasts and Estuaries

Aegean's varied and extensive coastline provides feeding and nesting opportunities for many birds from gulls to terns, from waders to ducks and geese.

7. The Checklist of Birds in the Aegean

The checklist of the birds of Aegean is provided for information. The list of birds presented here is collected by using various bird databases; such as Avibase (http://avibase.bsc-eoc.org/), Kusbank (www.kusbank.com.tr). Studies by Karauz K.S. (1995), Karauz and Kıraç (1995), Karauz S, (1998); Oro *et al* (2000) and Güçlüsoy *et al* (2014) were collected and summarised in this list. Besides these, my own personal records were included. This list outlines the most complete information and data about the Aegean Region; however some of the rare species may not be included. The reader should take this like a baseline reference and not as a complete list of birds of the Aegean. The Aegean Sea Region is very large region and a complete list of birds is only achieved by contributions of numerous numbers of Institutions, ornithologists, NGOs; bird watchers, and even of local people. The list of birds is provided as the North Aegean and the South Aegean, by convenience.

Checklist of Birds in the Aegean:

Order	Family	Scientific Name	North Aegean	South Aegean
ANSERIFORMES	Anatidae	*Anas acuta*	*	*
		Anas crecca	*	*
		Anas platyrhynchos	*	*
		Anser albifrons	*	*
		Aythya ferina	*	*
		Aythya fuligula	*	*
		Aythya marila	*	
		Aythya nyroca	*	*
		Branta leucopsis	*	
		Branta ruficollis	*	
		Bucephala clangula	*	*
		Cygnus columbianus	*	
		Cygnus cygnus	*	*
		Cygnus olor	*	*

		Mareca penelope	*	*
		Mareca strepera	*	*
		Mergellus albellus	*	
		Mergus serrator	*	*
		Mergus merganser	*	
		Netta rufina	*	*
		Oxyura leucocephala	*	
		Spatula clypeata	*	*
		Spatula querquedula	*	*
		Tadorna ferruginea	*	*
		Tadorna tadorna	*	*
		Anser anser	*	*
		Melanitta Nigra	*	
GALLIFORMES	Phasianidae	*Alectoris chukar*	*	*
		Alectoris graeca	*	*
		Alectoris rufa	*	
		Coturnix coturnix	*	*
		Phasianus colchicus	*	
GAVIIFORMES	Gaviidae	*Gavia arctica*	*	
		Gavia stellata	*	
PROCELLARIIFORMES	Hydrobatidae	*Hydrobates pelagicus*	*	*
	Procellariidae	*Calonectris diomedea*	*	*
		Puffinus yelkouan	*	*
PELECANIFORMES	Pelecanidae	*Pelecanus crispus*	*	*
		Pelecanus onocrotalus	*	*
	Phalacrocoracidae	*Microcarbo pygmaeus*	*	*
		Phalacrocorax aristotelis	*	*
		Phalacrocorax carbo	*	*
CICONIIFORMES	Ardeidae	*Ardea alba*	*	*
		Ardea cinerea	*	*
		Ardea purpurea	*	*
		Ardeola ralloides	*	*
		Botaurus stellaris	*	*
		Bubulcus ibis	*	*
		Egretta garzetta	*	*
		Ixobrychus minutus	*	*
		Nycticorax nycticorax	*	*
	Ciconiidae	*Ciconia ciconia*	*	*
		Ciconia nigra	*	*
	Threskiornithidae	*Platalea leucorodia*	*	*
		Plegadis falcinellus	*	*
PHOENICOPTERIFORMES	Phoenicopteridae	*Phoenicopterus roseus*	*	*
		Phoeniconaias minor	*	
PODICIPEDIFORMES	Podicipedidae	*Podiceps cristatus*	*	*
		Podiceps grisegena	*	
		Podiceps nigricollis	*	*
		Tachybaptus ruficollis	*	*

ACCIPITRIFORMES	Accipitridae	*Accipiter brevipes*	*	*
		Accipiter gentilis	*	*
		Accipiter nisus	*	*
		Aegypius monachus	*	
		Aquila chrysaetos	*	*
		Aquila fasciata	*	*
		Aquila heliaca	*	*
		Aquila nipalensis	*	
		Buteo buteo	*	*
		Buteo rufinus	*	*
		Circaetus gallicus	*	*
		Circus aeruginosus	*	*
		Circus cyaneus	*	*
		Circus macrourus	*	*
		Circus pygargus	*	*
		Clanga clanga	*	*
		Clanga pomarina	*	*
		Gypaetus barbatus		*
		Gyps fulvus	*	*
		Haliaeetus albicilla	*	*
		Hieraaetus fasciatus	*	*
		Hieraaetus pennatus	*	*
		Milvus migrans	*	*
		Milvus milvus	*	*
		Neophron percnopterus	*	*
		Pernis apivorus	*	*
	Pandionidae	*Pandion haliaetus*	*	*
FALCONIFORMES	Falconidae	*Falco biarmicus*	*	*
		Falco cherrug	*	
		Falco columbarius	*	*
		Falco eleonorae	*	*
		Falco naumanni	*	*
		Falco peregrinus	*	*
		Falco subbuteo	*	*
		Falco tinnunculus	*	*
		Falco vespertinus	*	*
GRUIFORMES	Gruidae	*Grus grus*	*	
	Rallidae	*Crex crex*	*	
		Fulica atra	*	*
		Gallinula chloropus	*	*
		Porphyrio alleni		*
		Porzana porzana	*	
		Rallus aquaticus	*	*
		Zapornia parva	*	*
		Zapornia pusilla	*	*
	Otidae	*Tetrax Tetrax*	*	
CHARADRIIFORMES	Haematopodidae	*Haematopus ostralegus*	*	*

	Recurvirostridae	*Himantopus himantopus*	*	*
		Recurvirostra avosetta	*	*
	Burhinidae	*Burhinus oedicnemus*	*	*
	Glareolidae	*Glareola nordmanni*	*	
		Glareola pratincola	*	*
	Charadriidae	*Charadrius alexandrinus*	*	*
		Charadrius asiaticus	*	
		Charadrius dubius	*	*
		Charadrius hiaticula	*	*
		Charadrius leschenaultii	*	*
		Eudromias morinellus	*	*
		Pluvialis apricaria	*	*
		Pluvialis squatarola	*	*
		Vanellus gregarius	*	
		Vanellus leucurus	*	*
		Vanellus spinosus	*	*
		Vanellus vanellus	*	*
	Scolopacidae	*Actitis hypoleucos*	*	*
		Arenaria interpres	*	*
		Calidris alba	*	*
		Calidris alpina	*	*
		Calidris canutus	*	*
		Calidris falcinellus	*	
		Calidris ferruginea	*	*
		Calidris melanotos	*	
		Calidris minuta	*	*
		Calidris pugnax	*	*
		Calidris temminckii	*	*
		Gallinago gallinago	*	*
		Gallinago media	*	*
		Limosa lapponica	*	*
		Limosa limosa	*	*
		Lymnocryptes minimus	*	*
		Numenius arquata	*	*
		Numenius phaeopus	*	*
		Scolopax rusticola	*	*
		Steganopus tricolor	*	*
		Tringa erythropus	*	*
		Tringa glareola	*	*
		Tringa nebularia	*	*
		Tringa ochropus	*	*
		Tringa stagnatilis	*	*
		Tringa totanus	*	*
		Xenus cinereus	*	
	Phalaropidae	*Phalaropus lobatus*	*	*
		Phalaropus fulicarius	*	
	Stercorariidae	*Stercorarius parasiticus*	*	

		Stercorarius skua	*	*
		Stercorarius pomarinus	*	
	Laridae	*Ichthyaetus audouinii*	*	*
		Ichthyaetus melanocephalus	*	*
		Chroicocephalus genei	*	*
		Chroicocephalus ridibundus	*	*
		Rissa tridactyla	*	
		Larus cachinnans	*	*
		Larus canus	*	*
		Larus fuscus	*	*
		Larus michahellis	*	*
		Larus armenicus	*	
	Sternidae	*Sterna hirundo*	*	*
		Sterna paradisaea	*	
		Sternula albifrons	*	*
		Thalasseus bengalensis	*	
		Thalasseus sandvicensis	*	*
		Chlidonias hybrida	*	*
		Chlidonias leucopterus	*	*
		Chlidonias niger	*	*
		Gelochelidon nilotica	*	*
		Hydrocoloeus minutus	*	*
		Hydroprogne caspia	*	*
COLUMBIFORMES	Columbidae	*Columba livia*	*	*
		Columba oenas	*	
		Columba palumbus	*	*
		Oena capensis	*	
		Streptopelia decaocto	*	*
		Streptopelia senegalensis	*	*
		Streptopelia turtur	*	*
PSITTACIFORMES	Psittaculidae	*Psittacula krameri*	*	*
CUCULIFORMES	Cuculidae	*Clamator glandarius*	*	*
		Cuculus canorus	*	*
STRIGIFORMES	Tytonidae	*Tyto alba*	*	*
	Strigidae	*Asio flammeus*	*	*
		Asio otus	*	*
		Athene noctua	*	*
		Bubo bubo	*	*
		Otus scops	*	*
		Strix aluco	*	*
CAPRIMULGIFORMES	Caprimulgidae	*Caprimulgus europaeus*	*	*
APODIFORMES	Apodidae	*Apus affinis*	*	
		Apus apus	*	*
		Apus pallidus	*	*
		Tachymarptis melba	*	*
CORACIIFORMES	Coraciidae	*Coracias garrulus*	*	
	Alcedinidae	*Alcedo atthis*	*	*

		Halcyon smyrnensis	*	*
	Meropidae	*Merops apiaster*	*	*
		Merops persicus	*	*
	Upupidae	*Upupa epops*	*	*
PICIFORMES	Picidae	*Dendrocopos major*	*	*
		Dendrocopos medius	*	*
		Dendrocopos minor	*	*
		Dendrocopos syriacus	*	*
		Jynx torquilla	*	*
PASSERIFORMES	Acrocephalidae	*Acrocephalus arundinaceus*	*	*
		Acrocephalus melanopogon	*	*
		Acrocephalus palustris	*	*
		Acrocephalus schoenobaenus	*	*
		Acrocephalus scirpaceus	*	*
		Hippolais icterina	*	*
		Hippolais languida	*	
		Hippolais olivetorum	*	*
		Hippolais polyglotta	*	
		Iduna pallida	*	*
	Aegithalidae	*Aegithalos caudatus*	*	*
	Alaudidae	*Alauda arvensis*	*	*
		Alaudala rufescens	*	*
		Calandrella brachydactyla	*	*
		Eremophila alpestris		*
		Galerida cristata	*	*
		Lullula arborea	*	*
		Melanocorypha calandra	*	*
	Bombycillidae	*Bombycilla garrulus*	*	
	Certhiidae	*Certhia brachydactyla*	*	*
	Cinclidae	*Cinclus cinclus*	*	
	Cisticolidae	*Cisticola juncidis*	*	*
	Corvidae	*Corvus corax*	*	*
		Corvus corone	*	*
		Corvus frugilegus	*	*
		Corvus monedula	*	*
		Garrulus glandarius	*	*
		Nucifraga caryocatactes	*	
		Pica pica	*	*
		Pyrrhocorax pyrrhocorax	*	
	Emberizidae	*Emberiza caesia*	*	*
		Emberiza calandra	*	*
		Emberiza cia	*	*
		Emberiza cineracea	*	*
		Emberiza cirlus	*	*
		Emberiza citrinella	*	*
		Emberiza hortulana	*	*
		Granativora melanocephala	*	*

		Schoeniclus pusillus	*	
		Schoeniclus schoeniclus	*	*
	Fringillidae	*Bucanetes githagineus*		*
		Carduelis carduelis	*	*
		Chloris chloris	*	*
		Coccothraustes coccothraustes	*	*
		Erythrina erythrina	*	*
		Fringilla coelebs	*	*
		Fringilla montifringilla	*	*
		Linaria cannabina	*	*
		Loxia curvirostra	*	
		Pyrrhula pyrrhula	*	
		Serinus pusillus	*	
		Serinus serinus	*	*
		Spinus spinus	*	*
	Hirundinidae	*Cecropis daurica*	*	*
		Delichon urbicum	*	*
		Hirundo rustica	*	*
		Ptyonoprogne rupestris	*	*
		Riparia riparia	*	*
	Laniidae	*Lanius collurio*	*	*
		Lanius excubitor	*	*
		Lanius minor	*	*
		Lanius nubicus	*	*
		Lanius phoenicuroides	*	
		Lanius senator	*	*
	Locustellidae	*Locustella fluviatilis*	*	*
		Locustella luscinioides	*	
		Locustella naevia	*	
	Motacillidae	*Anthus campestris*	*	*
		Anthus cervinus	*	*
		Anthus pratensis	*	*
		Anthus spinoletta	*	*
		Anthus trivialis	*	*
		Motacilla alba	*	*
		Motacilla cinerea	*	*
		Motacilla citreola	*	*
		Motacilla flava	*	*
	Muscicapidae	*Cercotrichas galactotes*	*	*
		Erithacus rubecula	*	*
		Ficedula albicollis	*	*
		Ficedula hypoleuca	*	*
		Ficedula parva	*	*
		Ficedula semitorquata	*	*
		Irania gutturalis	*	
		Luscinia luscinia	*	
		Luscinia megarhynchos	*	*

		Luscinia svecica	*	*
		Monticola saxatilis	*	*
		Monticola solitarius	*	*
		Muscicapa striata	*	*
		Oenanthe finschii	*	
		Oenanthe hispanica	*	*
		Oenanthe isabellina	*	*
		Oenanthe oenanthe	*	*
		Oenanthe pleschanka	*	*
		Phoenicurus ochruros	*	*
		Phoenicurus phoenicurus	*	*
		Saxicola rubetra	*	*
		Saxicola rubicola	*	*
	Oriolidae	*Oriolus oriolus*	*	*
	Panuridae	*Panurus biarmicus*	*	*
	Paridae	*Cyanistes caeruleus*	*	*
		Lophophanes cristatus	*	
		Parus major	*	*
		Periparus ater	*	*
		Poecile lugubris	*	*
	Passeridae	*Passer domesticus*	*	*
		Passer hispaniolensis	*	*
		Passer montanus	*	*
		Petronia petronia	*	*
	Phylloscopidae	*Abrornis inornatus*	*	*
		Abrornis proregulus	*	
		Phylloscopus collybita	*	*
		Phylloscopus trochilus	*	*
		Rhadina orientalis	*	*
		Rhadina sibilatrix	*	*
	Prunellidae	*Prunella modularis*	*	*
	Regulidae	*Regulus ignicapilla*	*	*
		Regulus regulus	*	*
	Remizidae	*Remiz pendulinus*	*	*
	Scotocercidae	*Cettia cetti*	*	*
	Sittidae	*Sitta europaea*	*	*
		Sitta krueperi	*	*
		Sitta neumayer	*	*
	Sturnidae	*Pastor roseus*	*	*
		Sturnus vulgaris	*	*
	Sylviidae	*Curruca cantillans*	*	*
		Curruca communis	*	*
		Curruca crassirostris	*	*
		Curruca curruca	*	*
		Curruca melanocephala	*	*
		Curruca mystacea	*	
		Curruca nisoria	*	*

		Curruca ruppeli	*	*
		Sylvia atricapilla	*	*
		Sylvia borin	*	*
	Troglodytidae	*Troglodytes troglodytes*	*	*
	Turdidae	*Turdus iliacus*	*	*
		Turdus merula	*	*
		Turdus philomelos	*	*
		Turdus pilaris	*	*
		Turdus torquatus	*	
		Turdus viscivorus	*	*

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GENETIC STUDIES ON THE AEGEAN SEA MARINE BIOTA

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1. Introduction

The Aegean Sea is an elongated embayment of the Mediterranean Sea located between the Greek and Anatolian peninsulas, between the main-lands of Greece and Turkey. In the north, it is connected to the Marmara Sea and Black Sea by the Dardanelles and Bosporus. The biodiversity and total biomass is being reduced in the Aegean Sea due to factors such as pollution, over-fishing, transportations and other anthropogenic effects. On the other hand, the global climate change increase the number of introduced invasive lessepsian species and put more pressure on native stocks. Due to these undesirable negative factors, there is a high demand on population genetic and phylogenetic studies to elucidate current status and structure of stocks and species in the Aegean Sea that allow us to take conservation actions. In this chapter, the population genetics and phylogenetic studies which have been conducted on the Aegean species are reviewed.

2. Genetic diversity of Species in the Aegean Sea

The Aegean Sea is connecting the Mediterranean Sea to the Marmara Sea via the Çanakkale Strait. The Marmara Sea is a very important biological corridor for many migratory species of fish and mammals from the Aegean Sea to the Black Sea. Moreover, the Aegean Sea play "acclimatization" role for transiting species to the Marmara and Black Seas. Therefore, the Aegean Sea may be a sieve to select or eliminate some genetic traits for the migratory species. Furthermore, there are other factors such as overfishing, tourism and climate change that cause variation in the genetic diversity of population of a species in the Aegean Sea. The Aegean Sea is under pressure of heavy fishing, high industrialized factories and tourism activities which cause pollutions and habitat degradations that constraints marine life. This kind of pressures seems to be shifting the marine species richness and structure and open a door for invasive species. The fishes and megafauna of the Aegean have been severely depleted during the last 10.000 years of exploitation and overfishing (Hogan and Sea, 2012). These practices have greatly reduced stocks of such commercially significant fish. In addition, warming of the Aegean Sea also increase the number of invasive species. In recent years, new lessepsian species have been increasingly observed in the Aegean Sea (Corsini *et al.,* 2005; Turan and Özturk, 2015), and there will probably be more invasion of the Red Sea species that results in more significant change of biodiversity in the Aegean Sea. Therefore, some endemic species can take the place with other lessepsian species. Over-fishing of native species result in decrease in native populations over time. A decrease in native species results in a formation of space and the abundance of nutrients which may generate presence of a suitable environment for the lessepsian species. Lessepsian species pressure on Aegean Sea marine life result in declining native species, and lessepsian species become common in these areas by establishing their diet tend to increase the reproductive ability. Therefore, genetic studies should be conducted especially on endangered or fragile species to elucidate genetic structure and take conservation actions accordingly.

3. Genetic Studies on the Aegean Sea Marine Biota

There are numerous population genetic and phylogenetic studies on population of a species in the Aegean Sea (Table 1) which are largely based on fishes, and limited numbers of studies were conducted on invertebrates and algal. Genetic and morphological techniques are commonly used to describe population structuring of a species in the Aegean Sea. There are also studies which show genetic variation between natural and aquacultured species in the Aegean Sea. Beside, numbers of aquaculted species are increasing in the Aegean Sea, and there should be more studies on the genetic effect of aquaculturing activities on the natural populations, so that conservation actions can be taken accordingly. On the other hand, there are limited numbers of studies on phylogeny of marine species of Aegean Sea. Morphological characters such as morphometrics, meristics, otolit shape and chemistry are commonly used characters for population identifications in the Aegean Sea that usually reflect genetic differentiation. Genetic markers such as protein electrophoresis, mtDNA RFLP analysis, microsatellites and DNA sequencing techniques have been commonly used for population and species identifications and also phylogenetic relationships.

Table 1. Description of population genetic and phylogenetic studies in the Aegean Sea.

Author	Marker	Species
Vidalis *et al*. (1997)	Multivariate analysis and Morphometrics	*Spicaru smaris*
Borsa *et al.* (1997)	Allozymes	*Platichthys flesus, P. stellatus*
Mamuris *et al.* (1998)	Multivariate analysis and Morphometrics	*Mullus barbatus*
Maltagliati *et al*. (1998)	Allozymes	*Nephrops norvegicus*
Mamuris *et al.* (1999)	Allozymes	*Mullus surmuletus*
Bahri-Sfar *et al.* (2000)	Microsatellites	*Dicentrarchus labrax*
Exdactylos and Thorpe (2001)	Allzyomes	*Solea solea, Scophthalmus rhombus, Pleuronectes flesus*
Turan and Basusta (2001)	Morphometrics	*Alosa fallax*
Lockyer *et al.* (2003)	mtDNA sequencing	*Phocoena phocoen*
Mattiangeli *et al.* (2003)	Minisatellite	*Trisopterus minutus*
Castillo *et al.* (2004)	Microsatellite	*Merluccius merluccius*
O'Reilly *et al.* (2004)	Microsatellite	*Theragra chalcogramma*
Turan (2004)	Morphologic differentiation	*Trachurus mediterraneus*
Turan *et al.* (2004)	Morphometric characters, Truss network system	*Engraulis encrasicolus*
Cımmurata *et al.* (2005)	Allzyomes	*Merluccius merluccius*
Erguden and Turan (2005)	Morphology and RFLP	*Dicentrarchus labrax*
Castilho And Ciftci (2005)	Microsatellites	*Dicentrarchus labrax*
Kotoulas *et al.* (2007)	Microsatellites	*Xiphıas gladius*
Stamatis *et al.* (2006)	Allzyomes	*Nephrops norvegicus*
Rolland *et al.* (2007)	Allzyomes	*Solea solea*

Tryfinopoulou *et al.* (2007)	mtDNA sequencing	*Sparus aurata*
Turan (2006a)	Otolith shape	*Trachurus mediterraneus*
Turan (2006b)	Allozyme and Morphology	*Mullus barbatus, Mullus surmuletus, Upeneus moluccensis, Upeneus pori*
Turan *et al.* (2006)	Morphology	*Pomatomus saltatrix*
Ivanova and Dobrovolov (2006)	Gel electrophoresis, Isoelectric focusing (IEF)	*Engraulis encrasicolus*
Kasapidis *et al.* (2007)	mtDNA sequencing	*Lagocephalus sceleratus*
Viaud-Martinez *et al.* (2007)	Morphology and mtDNA sequencing	*Phocoena phocoena*
Gurkan (2008)	Morphometric characteristic, Biometric analysis	Syngnathidae
Mattiucci *et al.* (2008)	Allozymes	*Trachurus trachurus*
Natoli *et al.* (2008)	Microsatellite	*Delphinus delphis*
Turan (2008)	mtDNA sequencing	Rajiformes
Bektas and Belduz (2009)	Multivariate analysis and Morphometrics	*Trachurus trachurus*
Erdoğan *et al.* (2009)	Allozyme	*Engraulis encrasicolus*
Erguden *et al.* (2009)	Morphometric and Meristic characters	*Scomber japonicus*
Maggio *et al.* (2009)	Microsatellite	*Mullus barbatus*
Turan *et al.* (2009a)	RFLP	*Trachurus trachurus*
Turan *et al.* (2009b)	RFLP	*Trachurus mediterraneus*
Turan *et al.* (2009c)	mtDNA sequencing	Scorpaeniformes
Arabacı *et al.* (2010)	Morphology	*Sparus aurata*
Turan and Yaglioglu (2010)	RFLP	*Sepia officinalis*
Minos *et al.* (2010)	mtDNA sequencing	Mugilidae
Davies *et al.* (2011)	Microsatellite	*Thunnus alalunga*

Merji *et al*. (2011)	mtDNA sequencing	*Pomatoschistus marmoratus*
Turan (2011)	mtDNA sequencing	*Spicara maena, Spicara flexuosa, Spicara smaris, Centracanthus cirrus*
Turan *et al.* (2011)	Morphological characters, Truss Network System	Mugilidae
Ibañez *et al.* (2007)	Morphological characters	Mugilidae
Karaoglu and Belduz (2011)	Morphological characters, Multivariate analyses	*Trachurus mediterraneus*, *T. picturatus.*
Borrell *et al.* (2012)	mtDNA sequencing	*Engraulis encrasicolus*
Yaglıoglu and Turan (2012)	mtDNA sequencing	*Saurida undosquamis*
Limborg *et al*. (2012)	Microsatellite	*Sprattus sprattus*
Keskin and Atar (2012)	mtDNA sequencing	*Engraulis encrasicolus*
Clusa *et al.* (2013)	mtDNA sequencing	*Caretta caretta*
Gurlek *et al.* (2013)	mtDNA sequencing	*Trachurus trachurus, Trachurus mediterraneus, Trachurus picturatus*
Gkafas *et al.* (2013)	Microsatellite and Morphometric and Meristic characters	*Oblada melanura*
Tuncay (2014)	Microsatellite	*Engraulis encrasicolus*
Turan and Güngör (2014)	RFLP	*Patella caerulea*
Gaspari *et al.* (2015)	Microsatellite	*Tursiops truncatus*
Turan (2015)	Microsatellite	*Sarda sarda*
Uyan and Turan (2015)	mtDNA sequencing and Morphometric and Meristic characters	*Chelidonichthys lucernus*
Turan *et al.* (2015a)	mtDNA sequencing	*Sarda sarda*
Turan *et al.* (2015b)	mtDNA sequencing	*Alosa caspia*, *A. fallax nilotica*, *Alosa maeotica*,

	Alosa immaculata, *Alosa tanaica*

Footnote: mtDNA; mitochondrial DNA, RFLP; restriction fragment length polimorphisim,

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CARTILAGINOUS FISHES AND FISHERIES IN THE AEGEAN SEA

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1. Introduction

Shark fisheries in the world expanded rapidly during 1980's due to the market demand. As a result of increased landings, by 2000's, almost all species of sharks became susceptible to fishery exploitation. The decrease in shark populations throughout the world has increased concerns over the elasmobranch stocks. Today, in many parts of the world, sharks fisheries are controlled by strict regulations and many species of sharks are protected. In the Mediterranean, elasmobranch landings have decreased from 25 000 tonnes in the 1980's to 7 000 tonnes in recent years and there is evidence that elasmobranchs are declining in abundance and diversity (Bradai *et al.,* 2012). Figures in Turkey, indicates that Elasmobranch landings reduced from 1535 tonnes in 2005 to 300 tonnes in 2014 with 43% of landings coming from the Aegean Sea (Tüik, 2014; Figure 1). In this region the majority of elasmobranch fishery is carried out by trawl, gillnet and longline fishing (Labropoulou and Papaconstantinou, 2000; Kabasakal, 1998a). However, mortality of incidentally caught elasmobranchs is believed to be significant, especially from trawl nets, gill nets, purse seines and longlines and may exceed mortality from directed fisheries (Peristeraki and Megalofonou, 2007).

In the Mediterranean, a total of 49 sharks and 36 ray species are known to exist (Bradai *et al*., 2012). More than 80% of these species are recognized as either vulnerable, endangered or critically endangered (Bradai *et al.,* 2012). The variability of habitats and hydrological conditions together with higher biological productivity in the north Aegean offer a variety of habitats for elasmobranchs in this region. As a result, the northern Aegean Sea and the Black Sea are considered as major fishing areas for sharks and rays in Turkey (Kabasakal, 1998a).

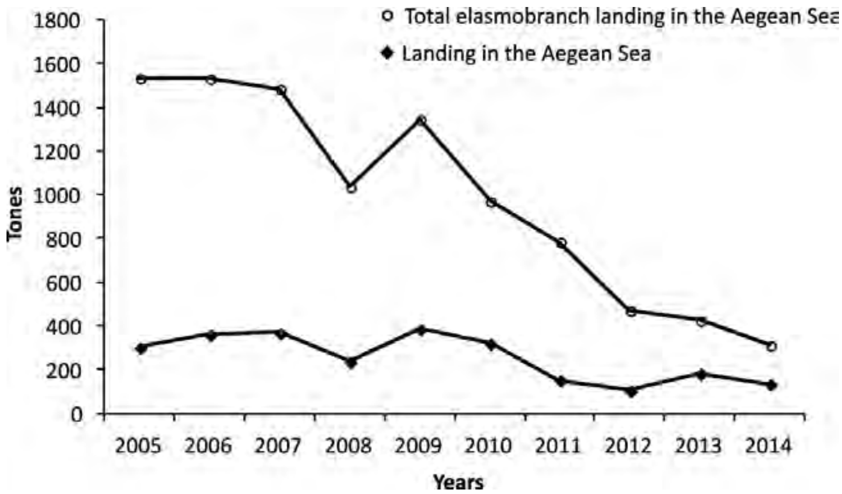

Figure 1. Elasmobranch landings during 2005-2014 period in Turkish waters (Tüik, 2014).

2. Biodiversity and Systematics of Sharks and Rays in the Aegean Sea

Worldwide, approximately 1169 species of cartilaginous fishes (Ebert and Winton, 2010) have been described, with approximately 179 new species named within the past decade (Carrier *et al.,* 2010). Throughout the world the elasmobranchs are the dominant chondrichthyan group, with approximately 56 families representing 96% of living species and the rest of the chondrichthyans include three chimaera families (Ebert and Winton, 2010). The sharks are more diverse than the batoids in terms of taxonomic groupings, but among all elasmobranch species there are more batoid species (54%) than shark species (42%) (Ebert and Winton, 2010). In the Mediterranean, a total 86 species of elasmobranchs occur (Bradai *et al.,* 2012). This number comprises 49 species of sharks from 17 families and 37 batoids species from nine families (Bradai *et al.,* 2012).

In the Aegean Sea, the Carchaniformes, Hexanchiformes, Lamniformes, Myliobatiformes, Rajiformes, Squaliformes, Squatiniformes and Torpediniformes are the most dominant groups in terms of abundance. A complete checklist of nominal chondrichthyan species in the Aegean Sea is presented in Table 1 (Bilecenoğlu *et al.,* 2014). Overall, 8 out of 10 chondrichthyan orders that occur in the Mediterranean and the Black Sea are found in the Aegean Sea.

Table 1. Diversity of Sharks and Batoids in the Aegean Sea by Order and Families

Order	Family	Species	Common name
	Sharks	*Heptranchias perlo*	Sharpnose sevengill shark
	Hexanchiformes	*Hexanchus griseus*	Bluntnose sixgill shark
Lamniformes	Alopiidae	*Alopias superciliosus*	Bigeye thresher
		Alopias vulpinus	Thresher
	Odontaspididae	*Carcharias taurus*	Sand tiger shark
	Lamnidae	*Odontaspis ferox*	Smalltooth sand tiger
		Carcharodon carcharias	Great white shark
		Isurus oxyrinchus	Shortfin mako
		Lamna nasus	Porbeagle
	Cetorhinidae	*Cetorhinus maximus*	Basking shark
Carcharhiniformes	Scyliorhinidae	*Galeus melastomus*	Blackmouth catshark
		Scyliorhinus canicula	Lesser spotted dogfish
		Scyliorhinus stellaris	Nursehound
	Sphyrnidae	*Sphyrna zygaena*	Smooth hammerhead
	Triakidae	*Galeorhinus galeus*	Tope shark
		Mustelus asterias	Starry smooth-hound
		Mustelus mustelus	Smooth-hound
		Mustelus punctulatus	Blackspotted smooth-hound
	Carcharhinidae	*Carcharhinus brevipinna*	Spinner shark
		Carcharhinus plumbeus	Sandbar shark
		Prionace glauca	Blue shark
Squaliformes	Dalatiidae	*Dalatias licha*	Kitefin shark
	Echinorhinidae	*Echinorhinus brucus*	Bramble shark
	Etmopteridae	*Etmopterus spinax*	Velvet belly
	Squalidae	*Squalus acanthias*	Picked dogfish
		Squalus blainvillei	Longnose spurdog
	Oxynotidae	*Oxynotus centrina*	Angular roughshark
	Centrophoridae	*Centrophorus granulosus*	Gulper shark
Squatiniformes	Squatinidae	*Squatina aculeata*	Sawback angelshark
		Squatina oculata	Smoothback angelshark
		Squatina squatina	Angelshark
Batoids			
Torpediniformes	Torpedinidae	*Torpedo nobiliana*	Electric ray
		Torpedo marmorata	Marbled electric ray
		Torpedo torpedo	Common torpedo
Rajiformes	Rhinobatidae	*Rhinobatos cemiculus*	Blackchin guitarfish
		Rhinobatos rhinobatos	Common guitarfish
	Rajidae	*Dipturus batis*	Blue skate
		Dipturus oxyrinchus	Longnosed skate
		Leucoraja circularis	Sandy ray
		Leucoraja fullonica	Shagreen ray
		Leucoraja naevus	Cuckoo ray
		Raja asterias	Mediterranean starry ray
		Raja clavata	Thornback ray
		Raja miraletus	Brown ray
		Raja montagui	Spotted ray
		Raja polystigma	Speckled ray
		Raja radula	Rough ray
		Raja undulata	Undulate ray
		Rostroraja alba	White skate
Myliobatiformes	Dasyatidae	*Dasyatis centroura*	Roughtail stingray
		Dasyatis pastinaca	Common stingray
		Dasyatis tortonesei	Tortonese's stingray
		Pteroplatytrygon violacea	Pelagic stingray

	Gymnuridae	*Gymnura altavela*	Spiny butterfly ray
	Myliobatidae	*Myliobatis aquila*	Common eagle ray
		Pteromylaeus bovinus	Bull ray
		Rhinoptera marginata	Lusitanian cownose ray
		Mobula mobular	Devil fish
	Chimaeridae	*Chimaera monstrosa*	Rabbit fish

3. Life Histories
3.1 Reproductive Biology

Chondrichthyans exhibit two main reproductive modes; oviparity and viviparity. Variations on these major reproductive modes are also observed. Oviparity is exhibited by members of the families Rajidae, Scyliorhinidae and Arhynchobatidae as well as by all members of the order Chimaeriformes. In oviparous species, eggs are enclosed within an egg case and deposited in the sea which are often attached to different substrates such as seaweeds and corals (Compagno, 1990). Since egg cases have morphological characteristics that are unique to each species they can succesfully be used in systematic studies (Ebert, 2005; Ebert and Davis, 2007; Carrier *et al.,* 2010). In viviparous species, the developing embryos are retained within the mother's uterus. In viviparity, two primary developmental modes, namely lecithotrophy and matrotrophy are observed (Musick and Ellis, 2005). In lecithotrophic viviparous species, the young do not receive maternal nourishment but are nourished by a yolk-sac during their development. In matrotrophic species, embryos receive maternal nourishment through the uterine wall (Musick and Ellis, 2005). The main reproductive parameters of 5 species from the Turkish waters of the Aegean Sea are summarised in Table 2. These data show that size at first sexual maturity of these species range between a minimum of 40 cm in *Raja radula* to a maximum of 88 cm in *Rostroraja alba* and indicate that these species reach sexual maturity in 5-8 years.

Table 2. Available reproductive parameters of elasmobranch species in the Aegean Sea. N: Sample size, TL: Total Length.

Scientific Name	Sex	N	Size at maturity, cm (TL)	References
Dipturus oxyrinchus	M	90	64-65	Yıgın and Ismen, 2010a
	F	89	82-83	
Rostroraja alba	M	59	75	Yıgın and Ismen, 2010b
	F	67	80	
Dasyatis pastinaca	M	32	62.5	Yıgın and Ismen, 2012
	F	52	62.5	
Squalus acanthias	M	274	52.8	Yıgın and Ismen, 2013
	F	346	56.4	
Raja radula	M	113	40	Yıgın and Ismen, 2014
	F	142	46	

3.2. Age and Growth

Information on longevity, growth characteristics and age at maturation allows calculation of growth and mortality rates and productivity. This information is very important for estimating the status of a population and assessing the risks of exploitation (Natanson *et al.,* 2007; Carrier *et al.,* 2010). Unlike fish, sharks and rays have traditionally been aged by examining seasonal changes in the deposition of growth bands in their vertebra (Cailliet and Goldman, 2004). Band counts can be correlated to age where the pattern of deposition has been shown to be annual. Spines, neural arches and caudal thorns are also commonly used for age determination in sharks and rays (Ketchen, 1975; Irvine *et al.,* 2006; McFarlane *et al.,* 2002; Gallagher *et al.,* 2006).

There are only 4 studies on the age and growth of elasmobranchs in the Turkish waters of the North Aegean Sea. These studies are given in Table 3 and report the growth of *Dipturus oxyrinchus*, *Rostroraja alba*, *Dasyatis pastinaca* and *Raja radula* in Saros Bay based on age and length. These results are similar to those reported in earlier studies in other regions in the Mediterranean. It has been shown that growth in sharks and rays is a factor of environmental parameters, prey abundance and differences in stock structure which may be specific to a particular region or habitat.

Table 3. Von Bertalanffy (1938) growth model (VBGM) parameters: L_∞ (mm TL), k (year^{-1}), t_0 (years).

Species	Sex	N	VBGM parameters			References
			L_∞ (cm)	K	t_0	
Dipturus oxyrinchus	M	35	251.81	0.04	-0.92	Yıgın and Ismen, 2010a
	F	30	233.88	0.04	-1.34	
	M+F	65	256.46	0.04	-1.17	
Rostroraja alba	M+F	126	254.83	0.05	-0.21	Yıgın and Ismen, 2010b
Dasyatis pastinaca	M	31	188.49	0.07	-0.04	Yıgın and Ismen, 2012
	F	52	119.96	0.09	-1.24	
	M+F	83	186.54	0.05	-1.40	
Raja radula	M	81	74.70	0.20	-0.22	Yıgın and Ismen, 2014
	F	111	82.94	0.16	-0.59	
	M+F	192	107.75	0.09	-1.40	

3.3. Feeding Ecology

Information about the feeding habits of sharks is essential because the quality of food directly affects the growth, maturation and mortality. In order to develop sound fisheries management and conservation strategies, description of diet, foraging habitat and predator-prey interactions of all species in a community is one of the most important steps (Bradai *et. al.* 2012). Sharks are considered as top predators and have an important role in the regulation of marine ecosystems at lower trophic levels. The mean trophic levels of sharks are similar to those of marine mammals (Pauly *et al.,* 1998). Sharks may shape their community through direct predation (Daly *et al.,* 2013) but a thorough understanding of their role on the ecosystem is lacking for many shark species due to lack of long term studies. Despite inherent difficulties and limitations in methodology, stomach content analysis has been an important tool to understand the trophic ecology of sharks.

Studies in the Aegean Sea report feeding habits of several species of sharks and rays based on stomach contents. These studies indicated that sharks and rays feed on a variety of organisms. Crustaceans and teleost fishes are the main preys of elasmobranchs (Türker Çakır *et al.,* 2006; Filiz and Taşkavak, 2006; Filiz, 2009; Kabasakal *et al.,* 2009; Karachle and Stergiou, 2010; Yıgın and Ismen, 2010c). Cephalopods are a major prey for *Squalus blainvillei*, *Scyliorhinus canicula*, *Galeus melastomus*, *Prionace glauca*, *Pteromylaeus bovinus* and *Myliobatis aquila* (Karachle and Stergiou, 2010; Bradai *et al.,* 2012). Sipunculids and echinoderms have minor importance as food (Filiz and Taşkavak, 2006). Some shark species may have unusual prey preference; for example, *O. centrina* is the only shark species ingesting polycheates (Bradai *et al.,* 2012). Yığın (2010) reported IRI (Index of Relative Importance) of prey items consumed by several members of the Rajidae family in the northern Aegean as follows: *Raja clavata*, crustacea 74.78%, fish 18.59%; *Raja miraletus*, crustacea 96.60%, fish 1.63%; *Raja radula*, crustacea 68.47%, fish 29.61%; *Rostroraja alba*, fish 75.20%, crustacea 1.10%; *Dipturus oxyrinchus*, crustacea 97.52% and fish 1.12%.

In the Mediterranean, there is also data on the feedings habits of one of the most studied shark species in the world: the white shark, *Carcharodon carcharias.* The main diet of this species in the Mediterranean includes mainly cartilaginous fishes (*Isurus sp*., *Myliobatis aquila*, *Dasyatis sp*.) and bony fishes (*Scomber scombrus*, *Thynnus thunnus*, *Sarda sarda*, *Lophius spp*. and *Belone belone*, *Merluccius merluccius*) and other preys such as marine turtles (*Chelonia mydas*) and cetaceans (*Delphinus sp*.) (Postel, 1958; Bradai, 2000; Kabasakal *et al.,* 2009).

4. Fisheries, Management and Conservation

Chondrichthyans constitute an ancient taxonomic group that was very abundant in the world oceans. Worldwide, their abundance has progressively declined over time and today many species of sharks are considered vulnerable or endangered (Fowler *et al*., 2005; Ferretti *et al.,* 2010; Maravelias *et al.,* 2012) due to overexploitation. Another important factor for the global decline of elasmobranchs is their longer life spans, slower growth rate, lower fecundity and late attainment of sexual maturity. These factors make elasmobranchs susceptible to changes in the ecosystem.

Studies carried out in central and western Mediterranean areas indicate declining population trends (Aldebert, 1997; Serena *et al.,* 2005). Similarly, Damalas and Vassilopoulou (2011) studied temporal variations in chondrichthyan catch rates of commercial fisheries in the Greek waters of the Aegean Sea and reported an overall abundance decline for the 1995-2006 period. There is a a similar trend in the Turkish waters of the Aegean Sea, Black Sea and Mediterranean (Figure 1). Keskin and Karakulak (2006) reported that some shark and ray species such as *Galeus melastomus, Raja radula, Dipturus oxyrinchus,* and *Torpedo marmorata* were found rarely in the northern Aegean Sea. Throughout the world, bottom trawling is considered as a major factor responsible for a large amount of by-catch of cartilaginous fish (Bonfil, 2002). In the Mediterranean Sea, the majority of the cartilaginous fish species are demersal and reports indicate over 10,000 tons of annual bycatch by bottom trawlers (FAO, 1995; Maravelias *et al.,* 2012).

Although chondrichthyans are among the more biologically sensitive fish species taken in European marine fisheries, their stocks are poorly studied. In the Aegean Sea, which is considered by the General Fisheries Council Mediterranean of the Food and Agriculture Organization (GFCM/FAO) as an independent management unit, very few studies on the abundance and distribution of demersal elasmobranch species have been conducted (Tserpes and Peristeraki, 2002; Maravelias *et al*., 2012). Maravelias *et al*. (2012), based on data from bottom trawl surveys in the Mediterranean Sea and the Aegean Sea, concluded that the most abundant cartilaginous fish species were *Scyliorhinus canicula* (Linnaeus, 1758) and *Raja clavata* (Linnaeus, 1758) representing more than 74% of the demersal elasmobranch abundance caught during 1998-2008 period. A list of studies on distribution, occurence, morphometrics and biodiversity of Elasmobranchs in the Turkish waters of the Aegean Sea are summarized in Table 4.

In Turkish waters of the the Black Sea and the northern Aegean Sea, Kabasakal (1998b) reviewed shark and ray fisheries caught by otter trawls, purse-seines, bottom longlines and gillnets. In Turkey, shark and ray meat consumption is rather limited and Elasmobranch catch is mainly processed for export. *Scyliorhinus canicula* individuals caught in northern Aegean Sea, are rarely larger than 50 cm and usually discarded. However, fins and livers of other sharks are processed and exported. For example, the meat of *S. acanthias* and *M. mustelus* are smoked or salted or marketed fresh as whole carcasses for export. Similarly, the wings of rays and skates are processed and marketed skinned and frozen (Kabasakal 1998b).

Despite several ongoing efforts on conservation and management of sharks and rays in the Mediterraanean, effective initiatives on conservation and fishery management is lacking in the Aegean Sea. Fish stocks in Turkey are diminishing due to overfishing and IUU fisheries (illegal, unreported, and unregulated fishing) in recent years (Öztürk, 2009). With respect to Elasmobranchs, currently, fishing of the sandbar shark, *Carcharhinus plumbeus,* basking shark*, Cetorhinus maximus,* school shark or the tope shark, *Galeorhinus galeus* and the porbeagle, *Lamna nasus* is prohibited in Turkish waters year-round. Regulations is limited to a few species and declaration of restricted areas for given species. For example, Gökova Bay, which is a breeding and nursery area for the sandbar shark, is a special environmental protected area. In Turkish fishery data, landings of elasmobranchs appear under generic names as "sharks" and "rays" and do not reflect the diversity of Elasmobranchs in Turkish waters at species level. Unfortunately, at least 28 shark species in Turkey are listed in IUCN red list (Fricke *et al*., 2007). Due to limited data at species level, fishing of many species of Elasmobranchs are not restricted despite declining populations. Therefore, there is an urgent need for species-specific fishing regulations based on reproduction period of many species of sharks and rays. Besides, Urgent exchange of information and cooperation with Greece to protect elasmobranchs in the Aegean Sea. Serious implementation also needed for the protection of the elasmobranch species all Turkish waters mainly Aegean Sea.

Table 4. List of studies on elasmobranchs in the Turkish waters of the Aegean.

References	Type of study	Region	Species
Kabasakal, 1998a	First records	Turkish coasts of the Aegean Sea	*Raja polystigma*
Keskin and Ünsal, 1998	Distribution	Gökçeada Island, NE Aegean Sea	*Torpedo marmorata, Torpedo nobiliana, Raja miraletus, Dasyatis pastinaca, Myliobatis aquila, Scyliorhinus canicula, Raja clavata*
Cihangir *et al.* 2004	Biodiversity	İzmir Bay, Aegean Sea	*Scyliorhinus canicula, Scyliorhinus stellaris, Mustelus asterias, Mustelus mustelus, Torpedo marmorata, Raja clavata, Raja miraletus, Raja radula, Dasyatis pastinaca, Gymnura altavela, Myliobatis aquila*
Kabasakal and Kabasakal, 2004	Distribution	Northern Aegean Sea	*Hexanchus griseus, Carcharodon carcharias, Lamna nasus, Cetorhinus maximus, Alopias vulpinus, Galeus melastomus, Scyliorhinus canicula, Scyliorhinus stellaris, Galeorhinus galeus, Mustelus asterias, Mustelus mustelus, Prionace glauca, Sphyrna zygaena, Etmopterus spinax, Oxynotus centrina, Dalatias licha,*

			Squalus acanthias, Squalus blainvillei, Squatina oculata, Squatina squatina
Keskin, 2004	Distribution	Gökçeada Island, NE Aegean Sea	*Dasyatis pastinaca, Raja miraletus, Myliobatis aquila, Torpedo nobiliana, Raja radula, Torpedo marmorata*
Torcu Koç *et al.,* 2004	Distribution	Saros Bay, northern Aegean Sea	*Squalus acanthias, Scyliorhinus canicula, Raja radula*
Filiz and Taşkavak, 2006	Morphological characteristics	Edremit Bay, the Northern Aegean Sea	*Scyliorhinus canicula*
Keskin and Karakulak, 2006	Distribution	North Aegean Sea	*Scyliorhinus canicula, Galeus melastomus, Squalus blainvillei, Etmopterus spinax, Rostroraja alba, Raja miraletus, Raja clavata, Raja asterias, Raja radula, Dipturus oxyrinchus, Torpedo marmorata*
Türker Çakır *et al.,* 2006	Reproduction and feeding	Edremit Bay, the Northern Aegean Sea	*Scyliorhinus canicula*
Kabasakal, 2007	Distribution	South-eastern part and Aegean coast	*Alopias superciliosus, Alopias vulpinus*
Kabasakal and Gedikoğlu, 2008	Occurrence	North Aegean Sea	*Carcharodon carcharias*
Filiz, 2009	Feeding	Aegean Sea	*Mustelus mustelus*
Ismen *et al.,* 2009	Length-weight relationships	Saros Bay, North Aegean Sea	*Etmopterus spinax, Galeus melastomus, Scyliorhinus canicula, Scyliorhinus stellaris, Hexanchus griseus, Heptranchias perlo, Mustelus asterias, Mustelus mustelus, Squalus acanthias, Squalus blainville, Carcharias taurus, Centrophorus granulosus, Mustelus punctulatus, Oxynotus centrina, Squatina squatina*
Kabasakal *et al.,* 2009	Occurrence	Northeastern Aegean Sea	*Carcharodon carcharias*
Yıgın and Ismen, 2009	Length-weight relationships	Saros Bay, North Aegean Sea	*Raja clavata, Raja miraletus, Raja radula, Rostroraja alba, Dasyatis pastinaca, Dipturus oxyrinchus, Myliobatis aquila, Dasyatis centroura, Gymnura altavela, Leucoraja naevus*
Bilge *et al.,* 2010	Length-weight relationships	Sığacık Bay, Aegean Sea	*Etmopterus spinax*

Ceyhan *et al.*, 2010	Catch and size selectivity	İzmir Bay, Aegean Sea	*Mustelus mustelus, Myliobatis aquila, Raja clavata, Dasyatis pastinaca, Scyliorhinus stellaris, Scyliorhinus canicula, Dipturus oxyrinchus, Rostroraja alba, Squalus acanthias, Raja asterias*
Düzbastılar *et al.*, 2010	Mortalities of fish		*Raja radula*
Yıgın and Ismen, 2010a	Age, growth, reproduction and feeding	Saros Bay, North Aegean Sea	*Dipturus oxyrinchus*
Yıgın and Ismen, 2010b	Age, growth, reproduction and feeding	Saros Bay, North Aegean Sea	*Rostroraja alba*
Yıgın and Ismen, 2010c	Feeding	Saros Bay, North Aegean Sea	*Raja clavata*
Altuğ *et al.*, 2011	Biodiversity	Northern Aegean Sea	*Scyliorhinus canicula, Squalus blainville, Squalus acanthias Oxynotus centrina, Torpedo marmorata, Dipturus oxyrinchus, Raja clavata, Raja miraletus, Raja radula, Dasyatis pastinaca, Myliobatis aquila*
Kabasakal *et al.*, 2011	Morphometric characteristics	Sivrice coast-NE Aegean Sea and Fethiye coast-eastern Mediterranean Sea	*Alopias superciliosus*
Keskin *et al.*, 2011a	Distribution	North-eastern Mediterranean	*Chimaera monstrosa, Galeus melastomus, Scyliorhinus canicula, Mustelus asterias, Etmopterus spinax, Squalus acanthias, Squalus blainvillei, Oxynotus centrina, Squatina squatina, Torpedo marmorata, Dipturus oxyrinchus, Raja asterias, Raja clavata, Raja miraletus, Raja radula, Dasyatis pastinaca, Myliobatis aquila*
Keskin *et al.*, 2011b	Distribution	North Aegean Sea (Eastern Mediterranean)	*Scyliorhinus canicula, Squalus acanthias, Squalus blainville, Oxynotus centrina, Torpedo marmorata, Dipturus oxyrinchus, Raja asterias, Raja clavata, Raja miraletus, Raja radula, Dasyatis pastinaca, Myliobatis aquila,*
Yıgın and Ismen, 2012	Age, growth and reproduction	Saros Bay, North Aegean Sea	*Dasyatis pastinaca*

Yıgın and Ismen, 2013	Reproduction	Saros Bay, North Aegean Sea	*Squalus acanthias*
Akyol and Capapé, 2014	First records	İzmir Bay, northeastern Aegean Sea	*Rhinobatos cemiculus*
Eronat and Özaydın, 2014	Length-weight relationships	Central Aegean Sea, İzmir Bay and Sığacık Bay	*Galeus melastomus, Scyliorhinus canicula, Scyliorhinus stellaris, Mustelus mustelus, Mustelus punctulatus, Etmopterus spinax, Squalus blainvillei, Torpedo marmorata, Dipturus oxyrinchus, Torpedo nobiliana, Raja asterias, Raja clavata, Raja radula, Rostroraja alba, Dasyatis pastinaca, Myliobatis aquila, Chimaera monstrosa, Heptranchias perlo, Galeorhinus galeus, Mustelus punctulatus, Oxynotus centrina, Dalatias licha, Dipturus batis, Leucoraja fullonica, Leucoraja naevus, Raja miraletus, Raja montagui, Raja polystigma, Dasyatis tortonesei, Gymnura altavela, Pteromylaeus bovinus*
Kabasakal, 2014	Status of the great white sharks	Northern, Central and South-eastern parts	*Carcharodon carcharias*
Keskin *et al.,* 2014	Landings and Discards	Northeastern Aegean Sea (eastern Mediterranean)	*Scyliorhinus canicula, Scyliorhinus stellaris, Raja clavata, Galeus melastomus, Dipturus oxyrinchus, Rostroraja alba, Raja miraletus, Dasyatis pastinaca, Raja montagui, Squalus acanthias, Mustelus mustelus, Myliobatis aquila, Torpedo marmorata, Etmopterus spinax, Chimaera monstrosa*
Yıgın and Ismen, 2014	Age, growth, reproduction and feeding	Saros Bay, North Aegean Sea	*Raja radula*
Akalın *et al.,* 2015	Length-weight relationships	Çandarlı Bay, North Aegean Sea	*Gymnura altavela, Torpedo marmorata*

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STATUS OF SMALL PELAGIC FISHES IN THE AEGEAN SEA

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1. Introduction

Although there are many definitions of "small pelagic fish," this expression most commonly refers to shoaling epipelagic fish characterized by high horizontal and vertical mobility in coastal areas and which, as adults, are usually 10–30 cm in length (Fréon *et al*., 2005). The upper limit is often debated, since some authors use the term "medium-sized pelagic fish" to designate larger fish than 20 cm (Bas *et al*., 1995). In this work, the term "small pelagic fish" is used for the fishes smaller than 20 cm.

Small pelagic fishes are essential renewable fisheries resources of the marine ecosystems due to their significant biomass at intermediate levels of the food web, playing a considerable role in connecting the lower and upper trophic levels (Rice, 1995, Bakun, 1996 and Cury *et al.*, 2000). Small pelagic fish species live in large schools in mid-water or upper layer of the water column (Fréon *et al*., 2005). They usually have a short life-span, become mature early and show rapid growth pattern. Ecologically, they are called as "r-strategist" selection. Anchovies and sardines are the most common species in this category.

Small pelagic fishes give large amounts of production all over the world including Turkish seas. Turkey has been taking the around 30th place in the world fish capture production. On average above 70% of the overall annual marine fish catch in Turkey is made up of a few small pelagic fish species such as anchovy, European pilchard and horse mackerel (SIS, 1985-2003; TurkStat, 2004-2014). Anchovy (*Engraulis encrasicolus*) is the most important small pelagic fish in terms of biomass and commercial interest for Turkish fisheries and alone comprise almost 65% of the overall marine fish catch (Gücü, 2012; SIS, 1985-2003; TurkStat, 2004-2014). There are almost twenty small pelagic fish species commercially exploited in the Turkish seas and this number is being increased due to lessepsian migration (Gücü, 2012). The other commercially important small pelagic fish species in Turkish seas whose catch data are collected and published by the Turkish official fishery statistics are European pilchard (*Sardina pilchardus*), sprat (*Sprattus sprattus*), horse mackerel (*Trachurus mediterraneus*), scad (*Trachurus trachurus*), chub mackerel (*Scomber colias*), sand smelt (*Atherina* spp.) and twaite shad (*Alosa fallax*).

The present chapter attempts to evaluate the recent state of some commercially important small pelagic fish species in the "Turkish Aegean Sea" based upon the official fishery statistics. Although these official landing statistics are likely to be inaccurate, the values given here provide consistent trends for the last thirty years. Additionally, in order to provide a general insight into their ecology in terms of reproduction biology, larval and trophic ecology, some studies mainly on the European pilchard have been done in the Turkish Aegean Sea are revised.

2. Catch Statistics (Landings) of Small Pelagic Fishes in the Aegean Sea

The Aegean Sea has a salinity variation between 33-39 ppt. The less saline Black Sea water comes through the Sea of Marmara to the northern Aegean Sea. The salinity is higher in the south. Although it is poorer in terms of nutrients compared to the Black Sea and the Sea of Marmara, the Aegean Sea is rich in the number of fish species. According to the recent marine fish checklist results a total of 512 species exist in the Turkish marine areas. The Aegean Sea has been showing the highest number of fish species as 449 taxa (Bilecenoğlu *et al*., 2014). Commercially exploited small pelagic fish species in the Aegean Sea are: *Sardina pilchardus, Sardinella aurita, S. maderensis, Alosa fallax, Sprattus sprattus* (Clupeidae), *Trachurus mediterraneus, T.trachurus, T.picturatus, Alectis alexandrines, Caranx crysos, C.rhonchus* (Carangidae), *Engraulis encrasicolus* (Engraulidae), *Atherina boyeri*, *A. hepsetus,* (Atherinidae) and *Scomber colias* (Scombridae).

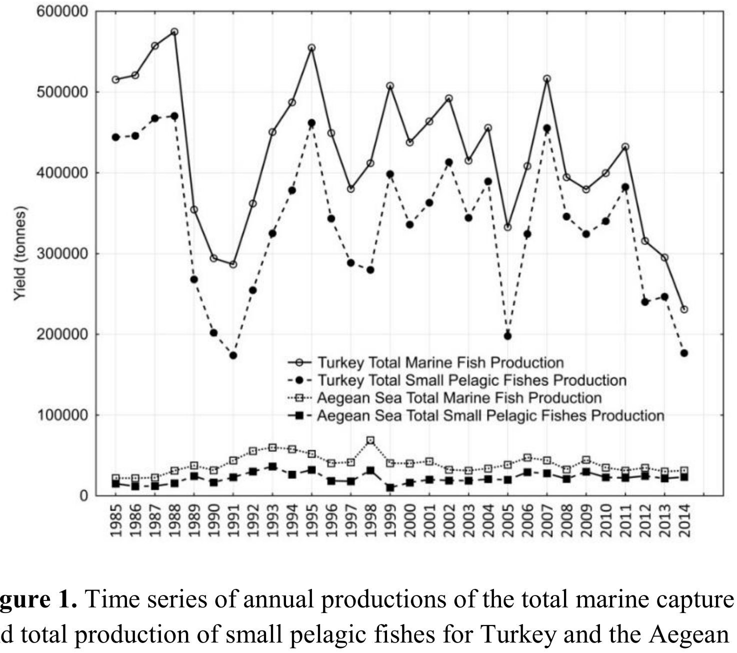

Figure 1. Time series of annual productions of the total marine capture fisheries and total production of small pelagic fishes for Turkey and the Aegean Sea.

Amounts of annual total marine fish catches in the Aegean Sea varied between 22000-69000 tonnes (SIS, 1985-2003; TurkStat, 2004-2014). The contribution of the Aegean Sea to the total marine landing of Turkey was on average 9 % (Figure 1). Small pelagic fishes from the Aegean Sea form more than 5 % of the overall marine fish production of Turkey. Annual overall marine fish production and annual small pelagic fish production rates showed similar distribution patterns in both Turkey and the Aegean Sea. There were some fluctuations in the annual catches of small pelagic fish species for short time periods.

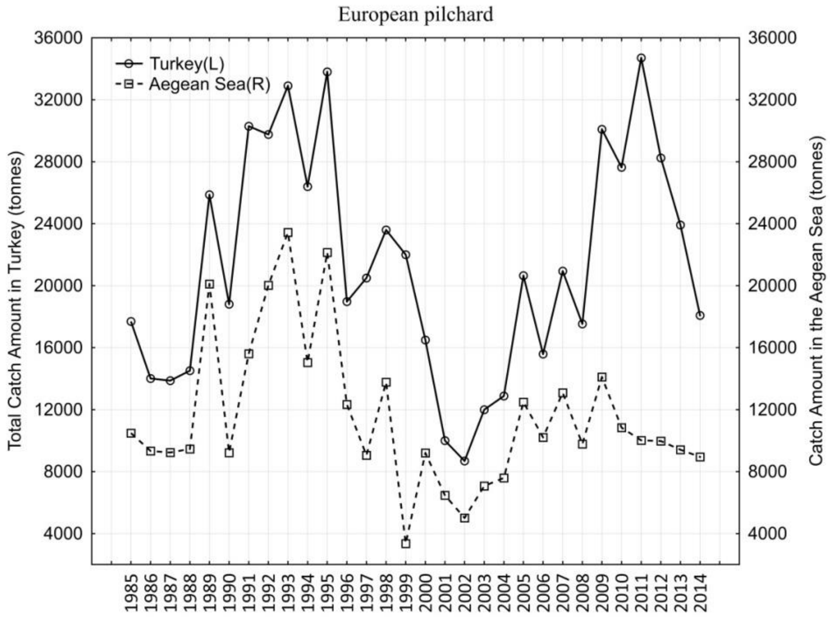

Figure 2. The annual catch statistics of the European pilchard for Turkey and the Aegean Sea

The most abundant fish species was the European pilchard and it forms more than 1/3rd of the total landings in the Aegean Sea. The majority of the European pilchard in Turkey was caught from the Aegean Sea (Figure 2). The catch amounts of the European pilchard showed an increasing trend until 1995. There was a sharp decline in 1996 and tended to decrease to its minimum values until 2002. Then, the catch amounts fluctuated during last 15 years and similar fluctuation pattern were observed in the catch amounts of the European pilchard in both the Aegean Sea and Turkey (Figure 2).

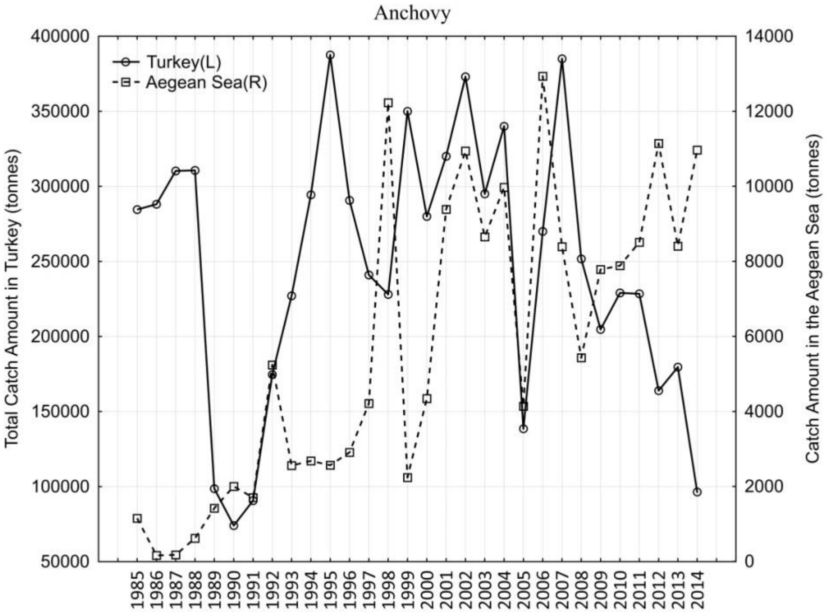

Figure 3. The annual catch statistics of anchovy for Turkey and the Aegean Sea

Anchovy followed the European pilchard in the catch statistics of the Aegean Sea (SIS, 1985-2003; TurkStat, 2004-2014). The recorded yields of the anchovy in the Aegean Sea were very low when compared to total landings of Turkey (Figure 3). However, the anchovy landings showed tendency to increase in the Aegean Sea, while the total anchovy landings tended to decrease. Similarly, the recorded yield of anchovy in the Aegean Sea increased while the European pilchard yields decreased.

Gücü (2012) suggested that the fluctuations in the landings of these two small pelagic fish species happened due to changes in temperature of seawater. European pilchard and anchovy share the same habitats but their temperature requirements were different. Anchovy and pilchard population dynamics and distribution patterns are known to be strongly dependent on the environment (Bonanno *et al*., 2014). Pilchard exhibits a stronger selective behavior, showing higher densities at shallower waters (up to 70 m depth in the Strait of Sicily and up to 50 m depth in the North Aegean Sea) whereas anchovy shows selective behavior up to the 100 m isobaths (Bonanno *et al.,* 2014). European pilchard is a cold loving species while anchovy enjoys the warmer marine environments. Gücü (2012) pointed out that because of the warm waters intruded into the Aegean Sea the landing of European pilchard reached a maximum value in the first half of 1990s and dropped remarkably leaving its place to the anchovy.

Two closely related small pelagic fish species scad (*Trachurus trachurus*) and horse mackerel (*Trachurus mediterraneus*) were the other important fisheries resources in the Aegean Sea (SIS, 1985-2003; TurkStat, 2004-2014). The landings of scad varied between 204-2496 tonnes (Figure 4). While one notable catch occurred in 1993 as 2000 tonnes, the maximum landings were observed around 2000-2500 tonnes between 2006 and 2009 (Figure 4).

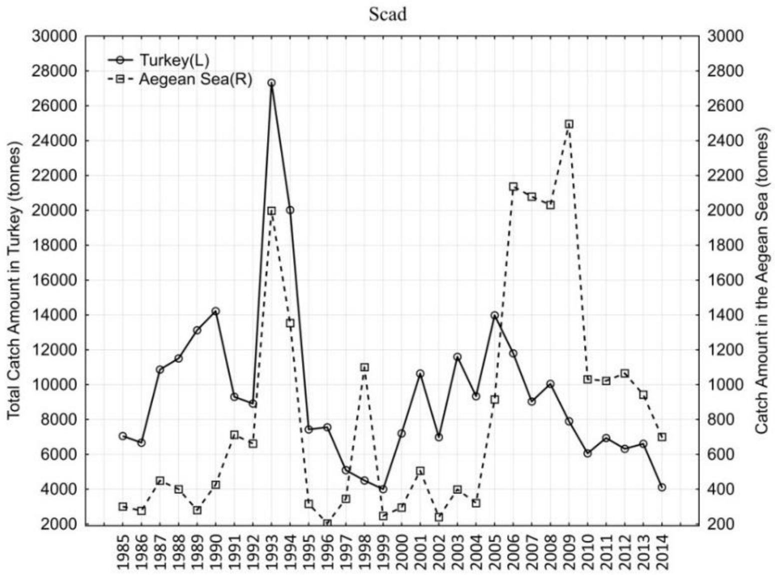

Figure 4. The annual catch statistics of scad for Turkey and the Aegean Sea

The total landings of horse mackerel decreased sharply after 1989 from 100 thousand tonnes to around 15 thousand tonnes in Turkey (Figure 5). However, the landings of horse mackerel showed also fluctuations in the Aegean Sea but the catch amounts did not highly vary like Turkey. While the minimum recorded yield of the horse mackerel was 178 tonnes in 1995, the maximum landing was 2000 tonnes in 1988 in the Aegean Sea (Figure 5).

The other major component of the small pelagic fish species in the Aegean Sea was chub mackerel. Total landing of chub mackerel in Turkey showed a decline trend after 1988 (Figure 6). The total catch amount of chub mackerel dropped from 32280 tonnes in 1988 to 1500 tonnes in 2002. There were no significant variations in the landings of chub mackerel after 2002 in Turkey. The landings of chub mackerel exhibited a similar distribution pattern in also Aegean Sea but after 1995. Chub mackerel catches somewhat oscillated with three notable peaks of 6708, 5470 and 6693 tonnes in 1993, 1994 and 1995, respectively (Figure 6).

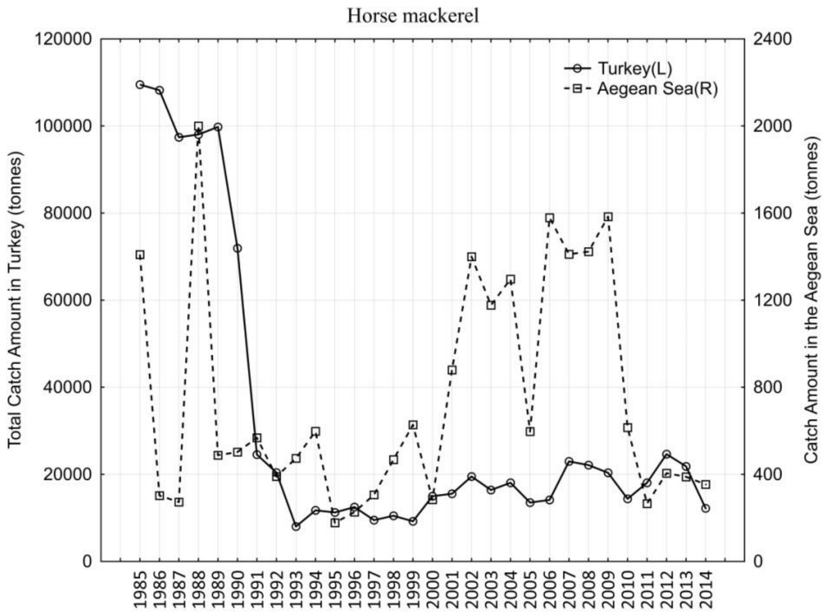

Figure 5. The annual catch statistics of horse mackerel for Turkey and the Aegean Sea

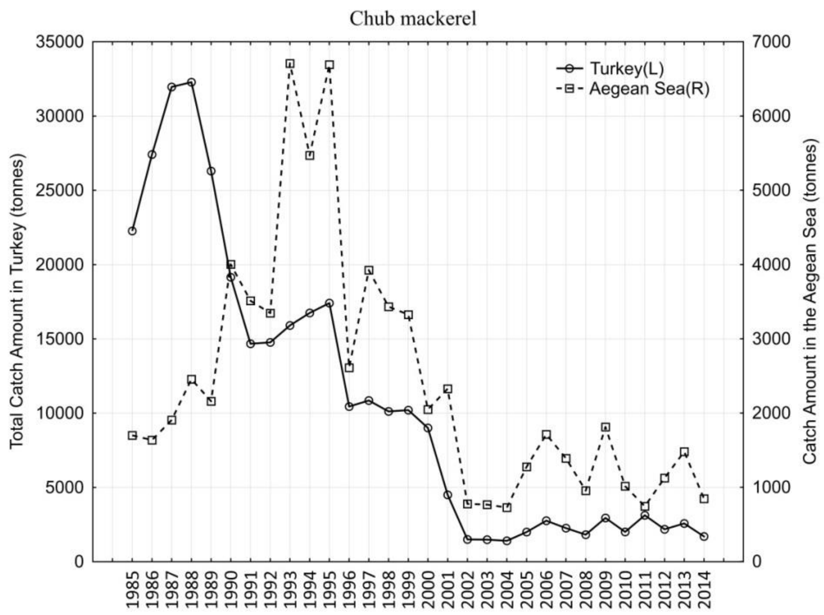

Figure 6. The annual catch statistics of chub mackerel for Turkey and the Aegean Sea

Twaite shad was the other commercially important small pelagic fish species in the Aegean Sea. More than half of this species were caught from the Aegean Sea during last 20 years. The landings of the twaite shad showed an annual increasing tendency (Figure 7).

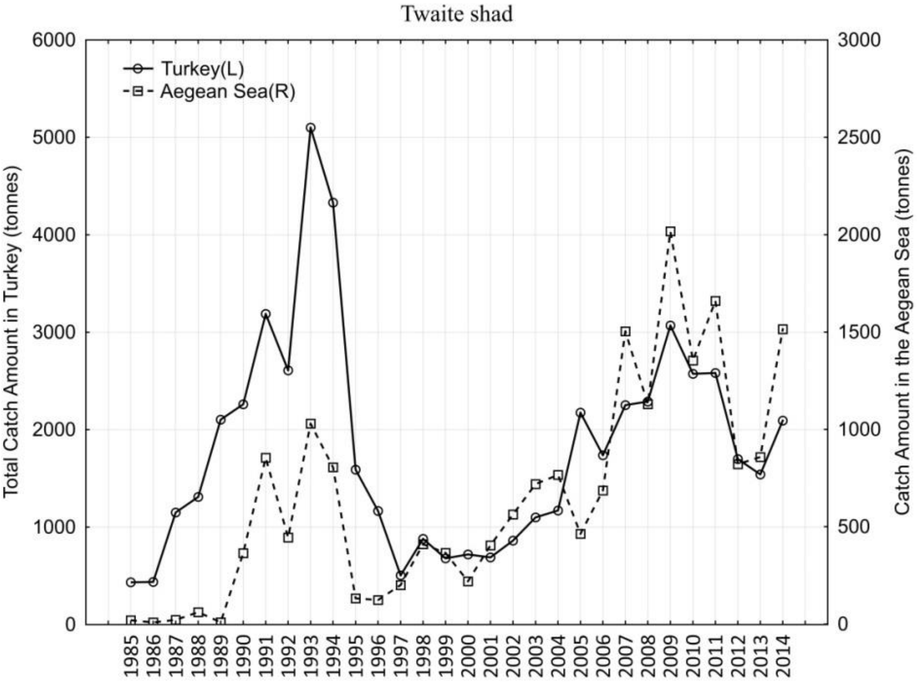

Figure 7. The annual catch statistics of twaite shad for Turkey and the Aegean Sea

Sprat and sand smelt were the other commercial small pelagic fishes in the Aegean Sea. Their annual catch statistics were shown in Figure 8 and 9, respectively.

Sprat were caught in the Aegean Sea from time to time and its catch amounts were low (Figure 8). Sprat displayed three notable peaks of 95, 231 and 145 tonnes in 2001, 2008 and 2010, respectively.

Sand smelt is also caught relatively in very small amounts in both the Aegean Sea and the Turkey for 20 years (Figure 9). There were two exceptional catch in 1988 and 1994 in the Aegean Sea.

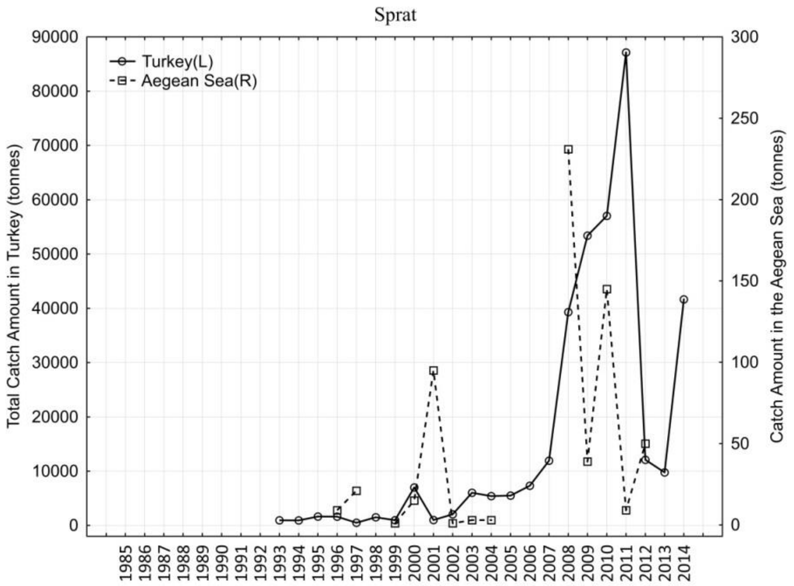

Figure 8. The annual catch statistics of sprat for Turkey and the Aegean Sea

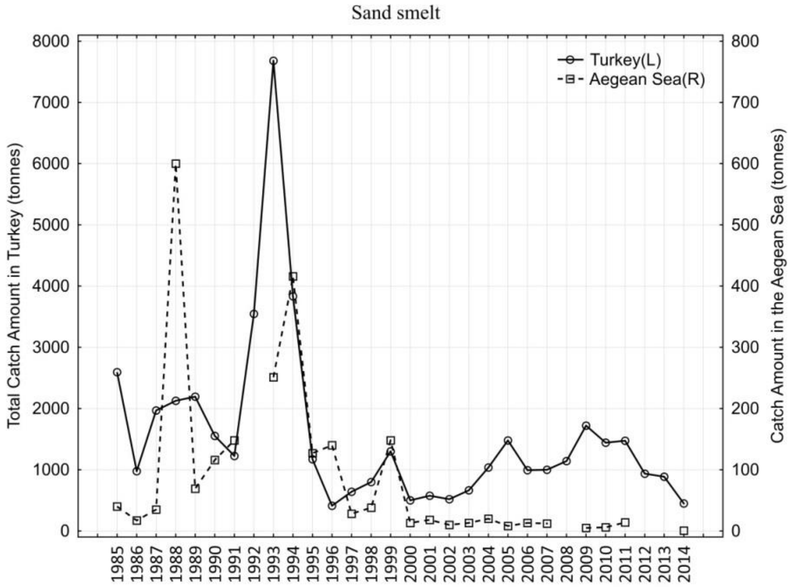

Figure 9. The annual catch statistics of sand smelt for Turkey and the Aegean Sea

3. The European Pilchard (*Sardina pilchardus*) in the Aegean Sea

European pilchard is one of the most important and dominant small pelagic fish species in the Aegean Sea. Coastal pelagic, it can be easily distinguished from the other family members by the lower part of gill cover bony striae (3-5 distinct) radiating downward. Mainly feed on planktonic crustaceans. Size usually between 15-20 cm.

Condition factor of the European pilchard varied between were 0.7 and 1.1. The maximum values observed in the end of the Autumn. The growth values of the European pilchard were L_∞□□.33 cm, k -0.17, t0 3.14 and W_∞ 107.9 g. The “b value” of the length-weight relationship found to be from 2.5 to 3.5 during a year period.

The Reproduction period of the European pilchard along the Turkish coast of the Aegean Sea extends from September to May (Cihangir, 1995). The GSI values represented same reproduction period in Edremit Bay and İzmir Bay (Figure 10 and 11).

The maximum GSI index values were observed in the months of December, January and February which the sea water have the lowest temperatures.

Lengths at first maturity of European pilchard were found to be 12.0 cm for female and 12.7 cm for male in the Aegean Sea (Figure 12).

As a multiple spawning indicator, it is possible to find various size of eggs all together in ovary during the reproduction period observed from the morphological and histological investigations (Figure 13). In European pilchard and other fishes with heterochronal spawners annual fecundity, the oocyte in active ovaries are typically distributed in different modes, each modes representing a single spawning batch (Hunter *et al.,* 1985). This situation can be seen (Figure 14) from the frequency distribution of oocyte diameter in the ovary of European pilchard throughout the year (Cihangir, 1996).

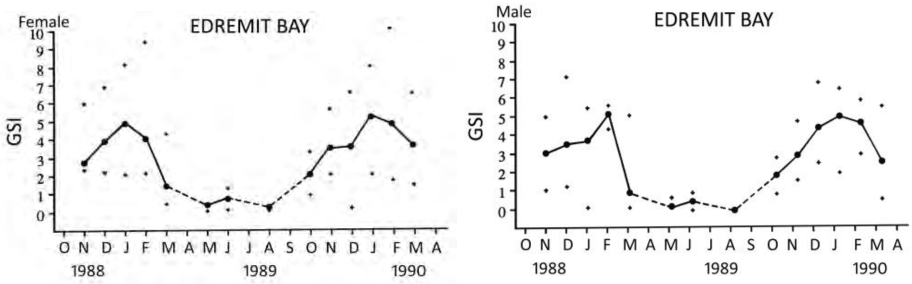

Figure 10. Gonadosomatic index (GSI) of European pilchard for both sexes in Edremit Bay, Aegean Sea (Cihangir, 1995)

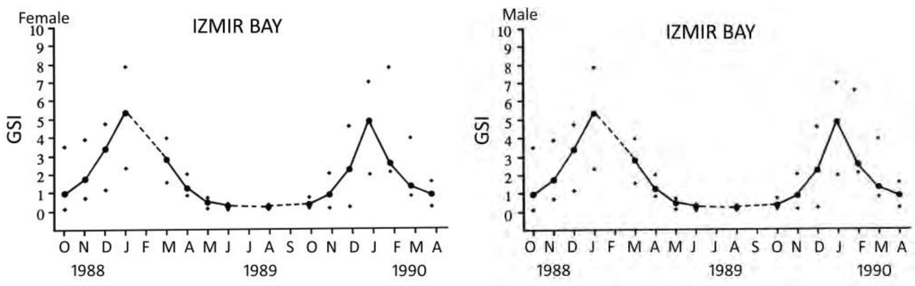

Figure 11. Gonadosomatic index (GSI) of European pilchard for both sexes in Izmir Bay, Aegean Sea (Cihangir, 1995)

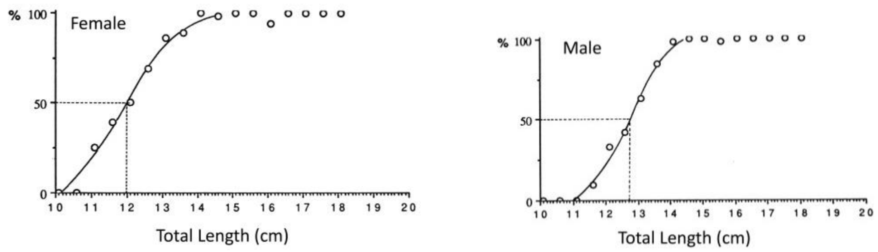

Figure 12. Mean length at first sexual maturation of European pilchard in the Aegean Sea (Cihangir, 1995)

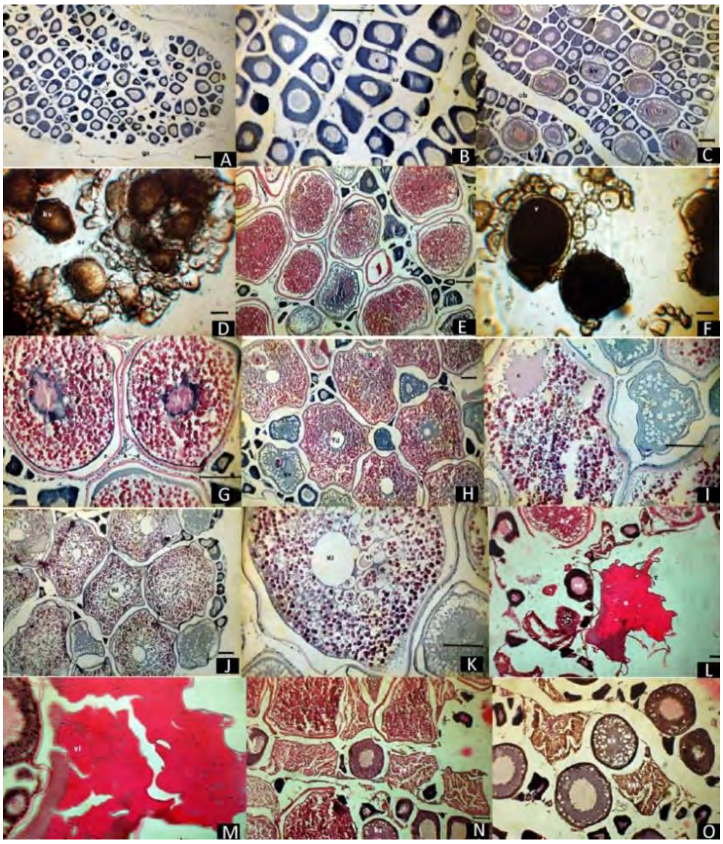

Figure 13. Histological and morphological appearance of pilchard ovary (Cihangir, 1996)

A. Immature ovary consisting of unyolked oocytes **B.** Enlargement of showing small, spherical unyolked oocytes with a large central nucleus. **C.** Maturing ovary with partly yolked oocytes. **D.** Maturing ovary with partly yolked oocytes morphology. **E.** Unyolked, partially yolked and yolked oocytes. **F.** Unyolked, partially yolked and yolked oocytes morphology. **G.** Fully yolked oocytes. **H.** Prespawning ovary showing oocytes in the migratory nucleus stage. **I.** Oocytes in the migratory nucleus stage. **J.** Oil globules and migratory nucleus stage. **K.** Enlargement of oil globules and migratory nucleus stage. **L.** At ovulation the post ovulatory follicle collapses away from the hydrated oocyte **M.** Enlargement of the hydrated oocyte. **N.** Follicle with the nuclei at the base of granulosa cell. Elapsed time from spawning a few hours. **O.** Enlargement of follicle age 0-day.

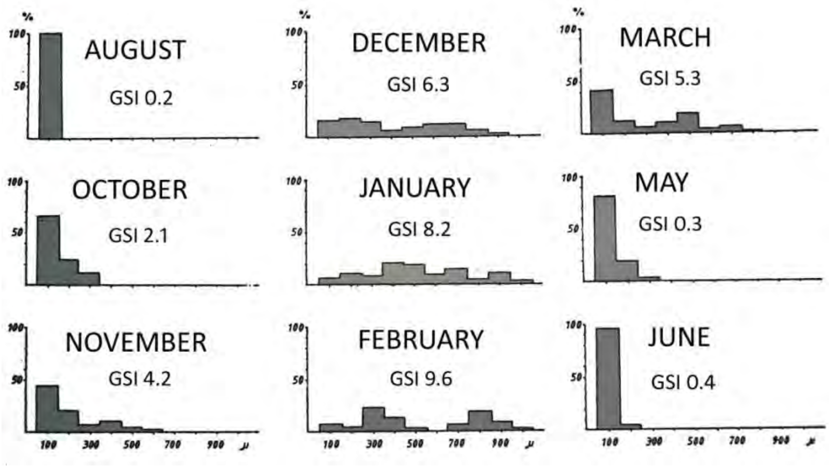

Figure 14. Frequency distribution of oocyte diameter in the ovary of European pilchard throughout the year (Cihangir, 1996)

The development rates of European pilchard eggs under different temperature regimes were done by Cihangir (1990) which is shown in Figure 15. According to Cihangir (1990), eggs can be hatched in three days at 13°C. European pilchard peak spawning time occurs during the late twilight and the maximum number of eggs can be found as around 500 individuals in a square meter in Izmir Bay (Cihangir *et al*., 2015).

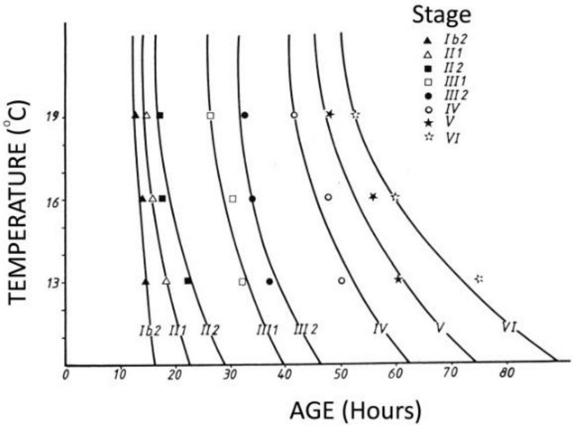

Figure 15. Development rates of European pilchard eggs under different temperature regimes (Cihangir, 1990)

Description of stages as fallows (Figure 16):
Ia 1- From fertilization to 64-cell stages.
Ia 2- Formation of the blsatodisc as a calotte.
Ia 3- Formation of the blastodisc as a flat lense.
Ib 1- Progression of blastoderm until yolk is covered up by ½
Ib 2- Progression of blastoderm until yolk is covered up by ¾
II 1- Progression of blastoderm until yolk is covered more than ¾. Blastopore still open.
II 2- Blastopore closed. Embryo surrounds yolk up to 180°.
III 1- Tail starts to separate from the yolk. The length of the free tail is smaller or equal than ½ the head length.
III 2- The length of the free tail is greater than ½ the head length.
IV -The tail extend ¼ the length of yolk sac.
V -The tail extend ½ the length of yolk sac.
VI -The tail greater than ¾ of the length of yolk sac and hatching.

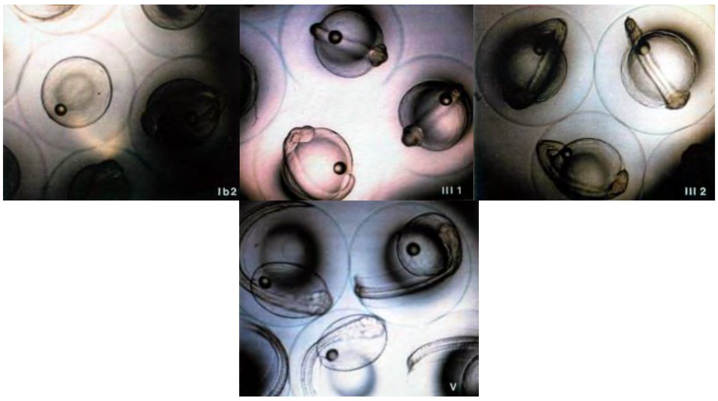

Figure 16. Various stages of European pilchard eggs (Cihangir, 1990)

Batch fecundity varies between 2000-20000 eggs ($Y=0.011457\ X^{4.8883}$ according to total length and $Y=33.134\ X^{1.5888}$ according to the gonad free weight) and spawning frequency is around one week for the Aegean Sea (Cihangir, 1992). The relationship of batch fecundity and total length, ovary free weight are shown in the Figure 17 and 18.

Abundance and distribution of European pilchard eggs and larvae as well as their development stages have been determined by Cihangir *et al.* (1998). In January, both eggs and larvae were found to be mainly concentrated in the middle of the outer bay, a few miles away from Gediz Estuary, at a density of about 800 eggs per square meter. The highest egg numbers has been found as 500-1500 eggs/m^2 in January in Izmir Outer Bay (Cihangir, 1995).

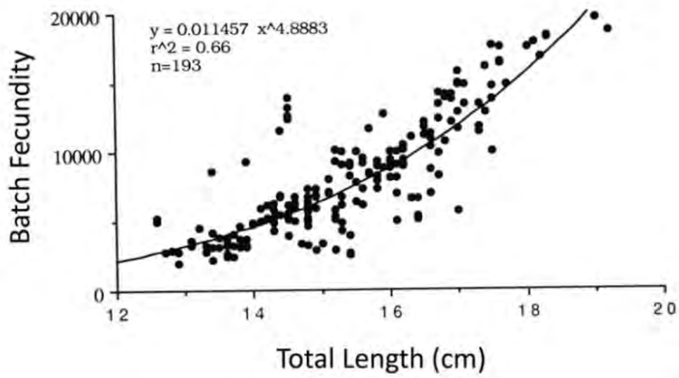

Figure 17. Batch fecundity- total length relation for European pilchard in the Aegean Sea (Cihangir, 1992)

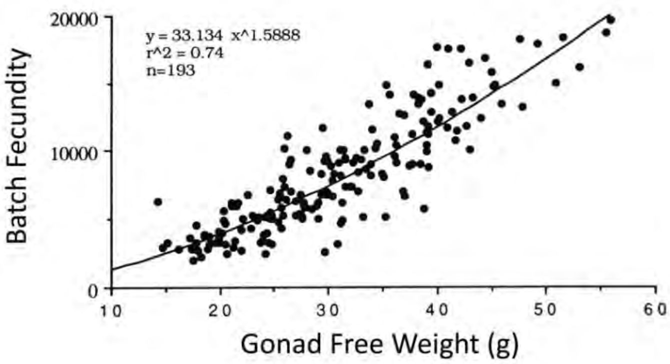

Figure 18. Batch fecundity- gonad free body weight relation for European pilchard in the Aegean Sea (Cihangir, 1992)

In January 1997, European pilchard eggs were also encountered in the inner bay (Inciralti vicinity) around 70-80 eggs per square meter, in spite of the pollution. Izmir Bay has been found as the one of the important spawning ground for the European pilchard in the Aegean Sea. The Izmir Bay, as a fishery ecosystem, plays all three major roles, i.e. as feeding, nursery and spawning grounds. Sardine juvenile were mostly located inshore, in semi-closed productive areas and often in proximity to river mouths as shown Figure 19 (Tsagarakis *et al*., 2008).

Recently, an European (Sixth Framework Programme) project carried out related with the small pelagic fishes in the whole Mediterranean Sea (SARDONE, 2010). Project is aimed at developing a series of tools to better understand stock assessment and fishery management of small pelagic fish resources (anchovy and sardine) of the Mediterranean. The three major stocks and fisheries the NW Mediterranean, the

Adriatic and the Aegean have been chosen. Investigation was aimed at detecting nursery areas, at developing echosurveys for recruitment strenght estimation, at filling the gap in knowledge on the ecology of late larvae and juveniles, at improving the selectivity of current fishing gear, at assessing the impact of fry fisheries on the stocks, at exploring the application of novel stock assessment methodologies to Mediterranean small pelagic stocks (Figure 20).

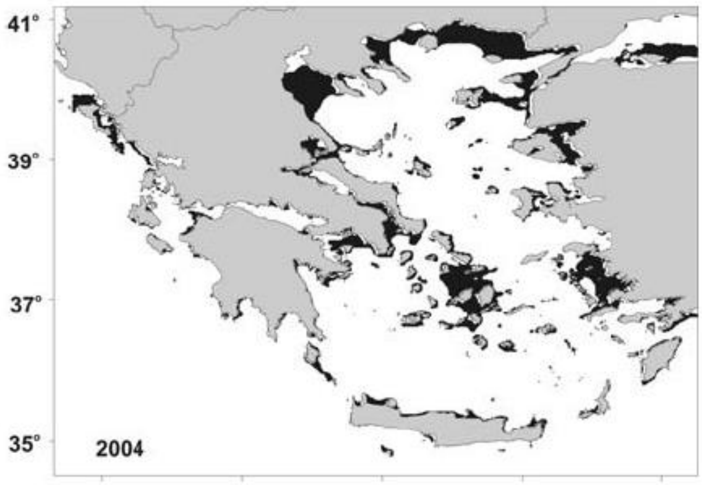

Figure 19. Geographic distribution of regions post classified as "juvenile sardine" areas for June 2004 (Tsagarakis *et al.,* 2008)

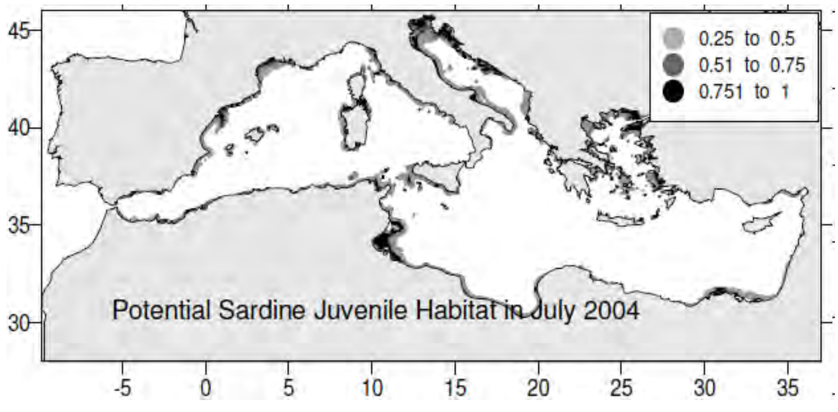

Figure 20. Potential sardine juvenile habitats in the whole Mediterranean Sea, (SARDONE, 2010)

4. Notes on fecundity and ichthyoplankton distribution of Anchovy in the Aegean Sea

Anchovy is a batch spawner, too. Batch fecundity of anchovy from Izmir Bay of the Aegean Sea was estimated by using "hydrated oocyte method" at the beginning of the reproductive season in April (Cihangir and Uslu, 1992). Batch fecundity is around 3 thousand eggs/female (Y= 0-9801.7+850.5 X according to the total length, and Y= 086.096+117.35 X according to the gonad free weight). Relative fecundity is around 100 eggs/g for female (Cihangir and Uslu, 1992). Abundance and distribution of anchovy eggs and larvae as well as their development stages have been determined by Coker *et al*. (1998) in Izmir Bay. In April, anchovy eggs were mostly distributed in the inner bay, around 700 eggs per square meter, in spite of the pollution. However, in September, the number of anchovy larvae was found to be only a few individuals per square meter in the same area. This clearly indicates that anchovy larvae cannot survive in the polluted area. The main spawning ground of the anchovy is located in the less polluted south eastern part of Uzunada Island where the maximum egg density found was 400 eggs per square meter at a water depth about 50 m.

5. Trophic Ecology of the Small Pelagic Fishes in the Aegean Sea

The food and feeding ecology of European pilchard, anchovy, Mediterranean horse mackerel, scad, twaite shad, the chub mackerel and the round sardinella (*Sardinella aurita*) have been studied by several researchers in İzmir Bay. Ünlüoğlu and Benli (2004) studied the stomach contents of European pilchard, anchovy and scad in İzmir Bay. Ünlüoğlu and Benli, 2004; reported that the copepods form the majority of diet composition of the European pilchard. Cladocerans, euphausids, crustacean larvae, pelagic polychaeta and eggs are the other prey organisms. Sever *et al.,* 2005 suggest that the European pilchard feeds on mostly copepods, and to a lesser extent on decapod crustacean larva and bivalves. *Oncea media, Centropages typicus*, *Calanoida, Once*a sp. and *Corycaeus* sp. are the dominant copepods.

The stomach contents of the anchovy consist of copepods, ostracods, fish eggs, decapod larvae, cladoceras and gastropods. Copepods were found primary prey organisms of anchovy (Ünlüoğlu and Benli, 2004).

The Mediterranean horse mackerel feeds on five major groups (Bayhan *et al*., 2013). Crustaceans (particularly copepods) proved to be most important food item and at least 58 different copepod species were identified. Mollusca, polychaeta, chaetognatha and fish eggs and larvae.

The stomach contents of scad were crustacea (copepod, euphausiacea and mysidacea), mollusca, Polychaeta, chaetognatha and fish eggs and larvae (Ünlüoğlu and

Benli, 2004; Bayhan and Sever, 2009). Copepods, euphausiids and mysids were thus the most important prey to be consumed by scad in all seasons as well as by the small size classes. Teleosts constituted the main food for larger specimens.

The primary food of twaite shad was found to be fish, especially anchovy. Decapoda, isopoda, ostracoda and copepod were the other prey organisms. Twaite shad was found to be a predator of the other small pelagic fishes and also some crustaceans (Ceyhan *et al.,* 2012).

The main food organisms of the juveniles of the chub mackerel were fishes, thaliceans (*Salpa* sp.), crustaceans (cladocera, ostracoda, copepod, mysidacea, isopoda, amphipoda, decapoda larvae and stomapoda), and polychaeta (Sever *et al.,* 2006).

The stomach contents of round sardinella, *Sardinella aurita*, consist of 48 different species belonging to siz major groups: polychaeta, crustacea, mollusca, chaetognatha, tunicate and teleostei. Crustaceans were the most important prey organisms for round sardinella (Bayhan and Sever, 2015).

6. Conclusion

Earlier, Cihangir and Tirasin, (1991) reviewed of European pilchard and anchovy fisheries in the Turkish waters. In this review, mainly European pilchard life cycle has been evaluated due to the commercial importance and the most abundant catches from the Aegean Sea. Small pelagic fish and fisheries in Turkish seas had been recently reviewed by Gücü (2012). As he mentioned that, European pilchard makes the 1/3rd of the total landings in the Aegean Sea. A decline of the anchovy stock has been noted in recent years, despite a low estimated exploitation rate, suggesting that environmental influences are at work.

Small pelagic fishes are essential “fast renewable” fisheries resources of the marine ecosystems. No updated scientific data are available in order to assess the fish stocks in the Turkish waters. To be able to achieve a sustainable use of these renewable living resources, an effective management plan ought to be developed on the reliable stock assessment. Improvements in fishing technology and power in the 1980s allowed fishing to be done outside of the bays, then after catches increased substantially, European pilchard makes up the largest share, anchovy reaches a higher price in the market and is thus more important and subject to heavier fishing pressure. According to the recent GFCM report (Farrugio, 1996): Situation of the Aegean Sea (Eastern Mediterranean GFCM Division 3.1) was formerly considered as an area of low biological productivity. In recent years, fishing power, landings and nutrient inflow from the Black Sea and incoming rivers in the western Aegean have increased and the role that environmental changes have actually played is put into question.

Fisheries management is mainly being conducted all over the area by season closure (April-September) for industrial fishing boats. Unfortunately fishing has been conducting without knowing the stock size (for any fish population) and any quota limitation; somehow a recent revised regulation has been prepared (not applied unfortunately) for anchovy, regarding each boat having its own quota limitation. Catch season of European pilchard is around all over the season (except season closure between mid of the April to September for only industrial fishing boats).

The authors suggest to employ "The Egg Production Method" (Lasker, 1985) in order to estimate the spawning stock sizes of European pilchard which are multiple spawners and widely distributed in the Aegean. In addition to the national projects, it will be mutually beneficial for the neighboring countries in the region to undertake joint bilateral or multilateral research projects in these waters.

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SOME OF THE SMALL PELAGIC FISHES FROM THE AEGEAN SEA

Sardina pilchardus

Engraulis encrasicolus

Scomber colias

Trachurus mediterraneus

DEMERSAL FISHES AND FISHERIES IN THE AEGEAN SEA

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1. Introduction

Turkey is located at the easternmost region of the Mediterranean Sea and surrounded by four major seas: The Black Sea, the Aegean Sea, the Levantine Sea, and the Sea of Marmara, all bearing different climatic and hydrographical regimes, geomorphologic structures and oceanographic conditions. The United Nations, Food and Agriculture Organization (FAO) includes these areas in FAO statistical area 37 (Mediterranean and Black Seas), which is further divided into sub-areas;1.1: Balearic; 1.2: Gulf of Lions; 1.3: Sardinia; 2.1: Adriatic Sea; 2.2: Ionian Sea; 3.1: Aegean Sea; 3.2: eastern portion of the Mediterranean Sea**,** referred to as Levantine Sea; 4.1: Marmara Sea; 4.2: Black Sea; and 4.3: Sea of Azov used by GFCM (Tsikliras *et al.,* 2015) Figure 1.

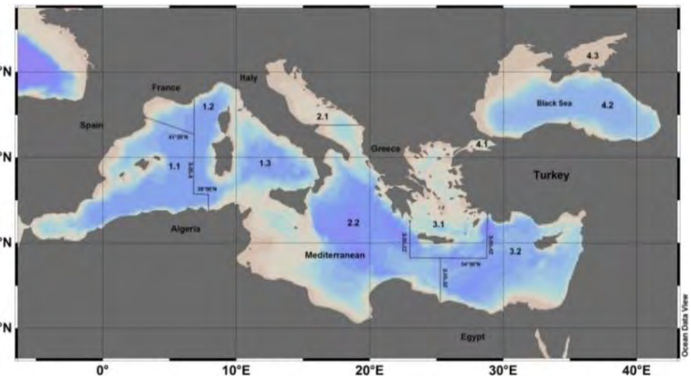

Figure 1. A map of the Mediterranean and Black Sea according to the GFCM division.

The Aegean Sea is located in the north-eastern Mediterranean. Turkey lies to the east and Greece to the north and west of the Aegean Sea. The Turkish zone in the Aegean Sea extends from the southern end of the Çanakkale Strait in the north, to the coastal city of Marmaris in the south. The Turkish waters of the Aegean Sea are relatively narrow with a width of 50 km in the north and 10-15 km in the south (Ulman *et al.,* 2013). The width of the Turkish territorial waters is 6 nautical miles in the Aegean Sea and 12 nautical miles in the Mediterranean Sea.

The North Aegean Sea is separated from the South Aegean Sea by the Cyclades islands located in Greek waters. The region has strong interaction with the Marmara and Black Seas and is one of the more productive areas due to the incoming Black Sea current. The Black Sea current is characterized by higher nutrient concentrations, colder temperatures (8.8-25°C) and less saline (31.8-38.3 psu) waters (Beşiktepe *et al*., 1994; Öztürk, 2009). The South Aegean is filled with warmer (14.6-24.7°C) and more saline (38.7-39.4 psu) oligotrophic waters characteristic of the eastern Mediterranean Sea. The bottom type on the shelf is mainly sand, with silt and clay sediments found predominantly on the slope (Keskin *et al*., 2011b). As a result of different ecological and hydrological conditions a wide number of fish species from different taxonomic groups inhabit a variety of habitats in Aegean Sea (Kocataş and Bilecik, 1992).

The main fishing grounds in Turkish territorial waters in the Aegean Sea are located in Saros Bay, around Gökçeada and Bozcaada islands, and in Edremit Bay in the north, Çandarlı Bay, İzmir Bay, Sığacık and Kuşadası Bay in the centre, and Güllük Bay and Gökova Bay in the south (Kınacıgil and İlkyaz, 2012; Keskin *et al.,* 2014) Fishing activities in this entire region are spatially limited due to the narrow continental shelf, the steep slope and its geomorphological characteristics. Due to existence of different habitats, fishing techniques in use in the Aegean Sea are highly diverse. The present chapter attempts to evaluate the recent status of the Aegean Sea's demersal fish fauna and fisheries. More specifically, composition of fish, the structure of fisheries and the state of exploitation in the Aegean Sea are given based on official fishery data.

1.1. Previous studies on the Aegean Sea fish fauna and fisheries

The scientific studies for composition and distribution of fish fauna in the Aegean Sea have been carried out by Akşiray (1987), Geldiay (1969), Mater (1976), Whitehead *et al.* (1986), Mater and Kaya (1986), Fischer *et al.* (1987), Kaya and Mater (1987), Kaya *et al.* (1989), JICA (1993), Mater and Meriç (1996), Torcu and Aka (2000), Metin *et al.* (2000), Bilecenoğlu *et al.* (2002), Mater *et al.,* (2002), Eryılmaz (2003) Cihangir *et al.* (2004), Doğanyılmaz-Özbilgin *et al*. (2006), Keskin *et al.* (2011a, 2011b), Cengiz *et al.* (2011), Gurbet *et al* (2013) and İşmen *et al* (2015). Akşiray (1987) reported a total of 443 pelagic and demersal fish species along the coasts of Turkey. In the Aegean Sea, a total of 337 pelagic and demersal fish species were reported (Mater and Meriç, 1996). Studies on the demersal fish compositon in the Aegean Sea are either local including major bays such as İzmir Bay or covers larger areas encompassing the entire northern or southern Aegean Sea. Mater (1976) gave a list of 16 Sparidae species from İzmir Bay. Mater and Kaya (1986) determined 7 species belonging to 4 genus of the family Gobiidae in Izmir Bay. Ulutürk (1987) reported species diversity and richness in the northern Aegean Sea and found 144 fish species around Gökçeada. Benli *et al.* (1999 and 2000) studied the species composition of catch, species diversity and estimation of the abundance of the commercial species and the average biomass of the demersal fish stocks of the Aegean Sea. A total of 34 species were of commercial interest in demersal fish assemblage in the northern Aegean Sea with *Mullus barbatus* and *Merluccius merluccius* being the most common species. Torcu and Aka (2000) determined 68 species in the Edremit Bay. Bilecenoğlu *et al.* (2002) gave a list of fishes of Turkey. Mater *et al.* (2002) gave taxonomical information on the recent status of 415 marine fishes inhabiting Turkish Seas and recorded 361 fish species in the Aegean Sea. Eryılmaz (2003) determined 92 species belonging to 44 families from Edremit Bay, Bozcaada Island andSaros Bay (Northern Aegean Sea). Bilecenoğlu *et al.* (2002) reported 388 fish species in the Aegean Sea of which 269 belonging to Atlanto-Mediterranean, 56 to Cosmopolitan, 44 to Mediterranean zoogeographical regions. Metin *et al.* (2000) observed 42 fish species in the Güzelbahçe area of Izmir Bay. Doğanyılmaz-Özbilgin *et al*. (2006) reported 52 species in Izmir Bay. Cihangir *et al.* (2004) gave diversity of the demersal fishes in the İzmir Bay between 1997 and 2003. The authors reported a total of 83 species, which included 4 shrimp species, 9 cephalopod species, 11 cartilaginous fish species and 59 bony fish species. Cengiz *et al*. (2011) determined the fish fauna of Saros Bay and identified 124 fish species belonging to 3 classis, 22 ordo and 59 families. Of these species, 28 belonged to cartilagonius and 96 to bony fishes. Keskin *et al*. (2011a) determined a total of 114 fish species in the north-eastern Levantina Sea and the north-eastern Aegean Sea which 64 belonged to the northern Aegean Sea fauna. Gurbet *et al.* (2013) reported a total of 112 species in İzmir Bay: 15 Chondrichthyes, 83 Osteichthyes, 11 Cephalopoda and 3 Crustacea. İşmen *et al*. (2015) examined the dispersion of the siganids in the Aegean Sea and reported one lessepsian species as the northernmost record off Assos coast, Edremit Bay in the north Aegean Sea. Demersalfaunal richness in the north-eastern Aegean Sea is mainly due to the outflow of cold, less saline and highly productive waters from the Black Sea.

The studies on stock assessment and distribution of demersal fish biomass in the Aegean Sea were carried out by Tokaç *et al.* (1991), JICA (1993), Kara and Gurbet (1999), Kara *et al.* (2000), Gurbet (2000), Benli *et al.* (2000), Tıraşın *et al.* (2005), Kınacıgil *et al.* (2008), Ünlüoğlu *et al.* (2008), Gurbet *et al*. (2009), Can *et al.* (2009), İşmen *et al.* (2010) and Keskin *et al*. (2011b). Tokaç *et al*. (1991) determined density distribution of demersal fish resources in İzmir Bay. Kara *et al.* (2000) studied density distribution of exploited demersal fish biomass in the continental shelf and offshore areas in ther Aegean Sea. Gurbet (2000) studied variations in the stock assessment and distribution of demersal fish biomass in the Northern Aegean Sea and total biomass of four commercial demersal fish species; red mullet, common pandora, hake and common sole was estimated as 458 tons. CPUE was calculated as 184 kg/km^2. Tıraşın *et al*. (2005) determined the seasonal standing biomasses of 42 bony fish species in İzmir Bay and the most abundant fishes in the catch compositions were red mullet (*Mullus* *barbatus*), annular seabream (*Diplodus annularis*) and blotched picarel (*Spicara flexuosa*). Öziç and Yılmaz (2006) investigated demersal fishes of Gökova Bay in the Aegean Sea and reported a total of 56 species; 15 cartilagonius and 41 bony fishes belonging to 2 classis, 14 ordo and 39 families. Of the 56 species reported, 45 were demersal and 11 were batydemersal. Kınacıgil *et al.* (2008) investigated growth parameters, first maturity length-age of demersal fishes in the central Aegean Sea (Foça, Gülbahçe Bay and northwest of Uzunada) and reported 90 fish species (14 cartilagonius, 76 bony fishes) belonging to 41 families. Ünlüoğlu *et al*. (2008) **s**tudied demersal fisheries resources of Edremit Bay. In their study, a total of 64 species were caught, including 5 crustaceans, 9 cephalopods, 9 cartilaginous fishes and 41 bony fishes. Some of the dominant fishes such as hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), poor-cod (*Trisopterus minutus capelanus*), and lesser spotted dogfish (*Scyliorhinus canicula*) constituted more than half of the total catch. The total biomass ranged from 663 to 1561 kg/km^2. Gurbet *et al.* (2009) determined the regional and seasonal effects of abiotic environmental factors on economical demersal fish population density and distribution in İzmir Bay. Can *et al*. (2009) reported temporal variability in abundance of demersal fish community from Izmir Bay. The contribution of Sparidae was 34.38%, followed by Serranidae 22.25%, Bothidae 15.09%, Mullidae 14.22%, Gobidae 3.71%, Centracanthidae 1.01% and Uranoscopidae 0.28%. Keskin *et al.* (2011a) reported comparison of fish assemblages between the West Marmara Sea and the North Aegean Seain relation to their biogeographical and environmental conditions and found 91 species belonging to 47 families. İşmen *et al.* (2010) studied the biomass and distribution of demersal fishes in Saros Bay and found that the dominant bony fishes were *Micromesistius poutassou*, *Mullus barbatus*, *Merluccius merluccius*, *Lophius budegassa*, *Trigla lyra*, *Citharus linguatula*, *Pagellus erythrinus*, *Pagellus acarne*, *Lepidorhombus boscii*, *Zeus faber*, *Mullus surmuletus*and *Chelidonichthys lucerna*. Keskin *et al.* (2011b) investigated distribution of the demersal fishes on the continental shelves of the Levantine and North Aegean Seas and found114 fish species; 84 in the north-eastern Levantine Sea and 64 in the north-eastern Aegean Sea. The most common species in the north-eastern Aegean Sea were *Serranus hepatus, Mullus barbatus, Citharus linguatula, Merluccius merluccius* and *Lepidotrigla cavillone*.

2. Demersal Fish Fauna

Mediterraean Sea ecosystem comprising semi-enclosed water bodies includes nearly 4% of marine fish species worldwide. In total, 650 fish species are known in the Mediterranean Sea (Keskin *et al.,* 2011b). Species richnessis increasing due to alien species coming from the Atlantic Ocean through the Gibraltar Strait and from the Indian Ocean through the Suez Canal. As a result of the increasing water temperaturesobserved after the mid-1980s, the difference of faunal composition in the Aegean Sea has increased from south to north.In recent years, 31 new species of lessepsian fishes have been observed in the South Aegean Sea while 53 were reported from the Mediterranean Turkish Coasts (Turan, 2010).

The number of bony fish species living in the Turkish seas is 415 (Bilecenoğlu *et al*., 2002; Çınar *et al.,* 2011; Tıraşın and Ünlüoğlu, 2012). The species richness in the Turkish Seas decreases from south to north with the most diverse bony fish fauna observed in the Mediterranean Sea and represented by 359 species. The Aegean Sea bony fish fauna is lower than that of the Mediterranean and includes a total of 344 species. A considerably fewer number of bony fish species (222) were reported from the Sea of Marmara. The Black Sea is inhabited by the least diverse bony fish fauna consisting of a total of only 147 species, less than half of that recorded for the Mediterranean and the Aegean Seas (Tıraşın and Ünlüoğlu, 2012).

The majority of the 415 bony fish species in the Turkish Seas are demersal in habitat selection and lives on or close to the bottom. The Aegean Sea demersal fish fauna includes a total of 245 species (%71 of total bony fish in the Aegean Sea). All these species are often caught by bottom trawling and constitute a large portion of Turkey's demersal fishery resources (Tıraşın and Ünlüoğlu, 2012). The Turkish official fishery data (2014) provides catch information for a total of 90 commercially important marine organisms (BSGM, 2015); 62 bony fish species, 3 cartilaginous fish groups and 25 invertebrate species. Of these 62 species of bony fishes, 41 are demersal species (Table 1). However, the actual total demersal fish catch in the Turkish territorial waters is much more diverse than reported numbers because data on several closely related species are combined and presented as a single taxonomic group. Similarly, although 54 demersal cartilaginous fish species were recorded for the Turkish Seas, only 3 taxonomic groups are referred to in the official statistics: sharks, ray and angleshark (Tıraşın and Ünlüoğlu, 2012; BSGM, 2015).

3. Demersal Fisheries in the Aegean Sea

The number of marine fishing boats in Turkey is around 15877 (Table 2) (BSGM, 2015). According to TUIK (2013), 4509 of the fishing boats are located in the Aegean Sea, corresponding to 32.8% of the total fleet. Fishing fleet in the Aegean Sea is composed of 53 bottom trawlers, 69 purse seiners, 46 carrier vessels and 4341 small-scale fishing boats (Table 3).

Table 1. The common names and distributions of demersal fish species whose catch data are published by TUIK, 2013). (BS) Black Sea, (MS) Marmara Sea, (ES) Aegean Sea, (MS) Mediterranean Sea.

Common Name	**Species Name**	**Origin**	**B S**	**M S**	**A S**	**M S**
Hake-European hake	*Merluccius merluccius*	AM	*	*	*	*
Red mullet	*Mullus barbatus*	AM	*	*	*	*
Golden banded	*Upeneus moluccensis*	IP			*	*
Seabream	*Sparus aurata*	AM		*	*	*
Common sole	*Solea solea*	AM	*	*	*	*
John dory	*Zeus faber*	C		*	*	*
Common seabream	*Pagrus pagrus*	AM			*	*
Angler fish	*Lophius piscatorius*	AM		*	*	*
Shore rockling	*Gaidropsarus mediterraneus*	AM	*	*	*	*
Meagre	*Argyrosomus regius*	AM			*	*
Painted comber	*Serranus scriba*	AM		*	*	
Black scorpion fish	*Scorpaena porcus*	AM	*	*	*	*
Annular bream	*Diplodus annularis*	AM	*	*	*	*
Brown meagre	*Sciaena umbra*	AM	*	*	*	*
Picarel	*Spicara smaris*	AM	*	*	*	*
Turbot	*Scophthalmus maximus*	AM	*	*	*	
Two banded bream	*Diplodus vulgaris*	AM	*	*	*	*
Gobies	*Gobius niger*	AM	*	*	*	*
Red gurnard	*Chelidonichthys cuculus*	AM	*	*	*	*
Trigla lineate	*Chelidonichthys lastoviza*	AM		*	*	*
Bogue	*Boops boops*	AM		*	*	*
Waker	*Epinephelus aeneus*	AM		*	*	*
Seabass	*Dicentrarchus labrax*	AM	*	*	*	*
Small-scalled	*Scorpaena notata*	AM	*	*	*	*
Saddled seabream	*Oblada melanura*	AM			*	*
Striped bream	*Pagellus erythrinus*	AM	*	*	*	*
Whiting	*Merlangius merlangus*	M	*	*	*	
European conger	*Conger conger*	AM	*	*	*	*
Striped seabream	*Lithognathus mormyrus*	AM		*	*	*
Croaker	*Umbrina cirrosa*	AM	*	*	*	*
Dusky grouper	*Epinephelus marginatus*	AM		*	*	*
Piper	*Trigla lyra*	AM		*	*	*
Large-eye dentex	*Dentex macrophthalmus*	AM			*	*
Flounder	*Citharus linguatula*	AM		*	*	*
Black sea bream	*Spondyliosoma cantharus*	AM		*	*	*
Saupe	*Sarpa salpa*	AM		*	*	*
Dentex	*Dentex dentex*	AM	*	*	*	*
Sharpsnout seabream	*Diplodus puntazzo*	AM	*	*	*	*
Striped red	*Mullus surmuletus*	AM	*	*	*	*
Blue spotted bream	*Dentex gibbosus*	AM		*	*	*
Saury	*Synodus saurus*	AM		*	*	*

AM: Atlanto mediderranean, IP:Indopacific, C:Cosmopolitan, M:Mediterranean

Table 2. Length distribution of fishing vessels in the Turkey, 2014 (BSGM, 2015)

Region	Length group (m)									Total
	0-4.9	**5-7.9**	**8-9.9**	**10-11.9**	**12-14.9**	**15-19.9**	**20-29.9**	**30-49.9**	**50+**	
Marine capture	794	9883	2978	802	435	284	462	233	6	**15877**
Inland capture	306	2431	223	30	60	15	0	0	0	**3065**
TOTAL	**1100**	**12314**	**3201**	**832**	**495**	**299**	**462**	**233**	**6**	**18942**

3.1. Small-scale fisheries

The fisheries in the Aegean Sea are dominated by the small-scale (artisanal) fisheries that use small wooden boats, 5-12 m in length and are crewed by one to two fishers. The smallfishing vessels compose approximately 95% of the total fleet in Aegean Sea (Table 2, 3). The daily catch per small vessel range from 2.0–7.2 kg/day (Ulman *et al.,* 2013) andtheir contribution to fish landings is only between 10-20% (Kara and Kınacıgil, 1990), but the catch composition of artisanal fisheries in general is composed of commercially important and highly prized fish and therefore, from economical point of view, its contribution to regional fisheries is higher. Small-scale vessels primarily use gill nets, trammel nets, entangled nets, long lines, pots and traps, spear fishing and lift nets and target red mullet, striped red mullet, common dentex, bonito, swordfish, common sole, bogue, sea bream, two banded sea bream, annular sea bream, saddled seabream, grouper, cuttlefish, octopus and squid (Tokaç *et al*., 2010; Kınacıgil and İlkyaz, 2012; Ulman *et al.,* 2013).

Lagoon fishery is also performed by small scale vessels using traps, nets and fyke netsin the Aegean Sea. Catch composition in lagoons are mainly composed of gilthead seabream, mullet, European seabass, common sole, European eel, striped seabream and blue crab. Karina and Köyceğiz lagoons have higher production capacities, followed by Güllük, Akköy, Homa, Peso, Cüzmene and Sakızburnu lagoons. The total production of lagoons along the Aegean coast is 400 tonnes fish and one ton caviar (Kınacıgil and İlkyaz, 2012).

3.2. Large-scale fisheries

Compared to extensive artisanal fisheries, arelatively minor industrial sector (large-scale) composed of trawlers and purse seiners operate in the Aegean Sea. Most of the industrial vessels come from the Black Sea to fish seasonally in the Aegean Sea (Ulman *et al.,* 2013). The purse seiners target small pelagics such as anchovy, horse mackerel and pilchard as well as some larger pelagics such as bonito and tuna (Ulman *et al.,* 2013). Catch from purse seine fisheryis significant and accounts for 80% of the capturemarine fish production. Primary features of nets used by purse seiners depend on the vessel type and characteristically range between 600-1200 m in length and 100-150 m in depth (Kınacıgil and İlkyaz, 2012). All purse seiners are equipped with fish finders to locate fish and vertical fish movements are monitoed by multi-beam sonars. In addition, many of these boats are equipped with radars and VHF radio receivers. Net hauling is performed mechanically by hydraulic net stowing pulleys. Due to lower daily catch, Aegean Sea purse seiners do not use carrier boats compared to purse seiners that operate in the Black Sea and the Sea of Marmara. Instead, 8-12 m long, one or two light boats are used during operation (Kınacıgil and İlkyaz, 2012).

Table 3. Number of fishing vessels carrying out fishing activities by regions, 2013.

Operating type	**Total**	**Black Sea**		**Marmara**		**Aegean**		**Mediterranean**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
	13727	**4899**	**35.7**	**2492**	**18.2**	**4509**	**32.8**	**1847**	**13.5**
Trawler	741	351	47.4	135	18.2	53	7.2	202	27.3
Purse seiner	454	197	43.4	128	28.2	69	15.2	60	13.2
Carrier vessels	173	89	51.4	30	17.3	46	26.6	8	4.6
Gill and trammel nets	8315	2991	36.0	1281	15.4	3175	38.2	868	10.4
Beam trol and dredges	297	150	50.5	131	44.1	9	3.0	7	2.4
Long line and lines	3421	1063	31.1	660	19.3	1001	29.3	697	20.4
Other	326	38	11.7	127	39.0	156	47.9	5	1.5

In the Aegean Sea, 90% of the demersal fish production is provided by bottom trawls. Trawl vessels vary between 15-25 m in length with 150-350 HP engines. All trawlers deploy and retrieve trawls from the stern and use traditional Mediterranean type trawl nets. Vessels are equipped with echo sounder, radar and VHF radio receivers. Fishes at depths up to 250 m can be targeted and only a few numbers of vessels can operate in international and deeper waters (Kınacıgil and İlkyaz, 2012). A variety of commercially important fish species are targeted by the bottom trawl fishery in the Aegean Sea including red mullet *Mullus barbatus,* European hake *Mercluccius merluccius*, common sole *Solea solea*, pandora *Pagellus* spp., poor cod *Trisopterus minutus*, whiting *Merlangius merlangus,* anglerfish *Lophius* spp., four-spot megrim *Lepidorhombus boscii*, Norwegian lobster *Nephrops norvegicus,* rose shrimp *Parapenaeus longirostris* and giant red shrimp *Aristeomorpha foliacea* (Tıraşın and Ünlüoğlu, 2012).

4. Catch-Landings

In Turkey, total production from fishing and aquaculture combined is 537345 tons (BSGM, 2015). While 50% of total production comes from capture marine fisheries, only 7% is inland capture fisheries and 44 % of total production comes from aquaculture (Table 4). Capture fishery production can be further divided into three main groups; pelagic-demersal fish species, crustaceas-molluscs and others.

Table 4. Capture and Aquaculture fish production (tons) in Turkey from 2000 to 2014 (BSGM, 2015)

Year	Capture Fisheries					Aquaculture			Turkey
	Marine			Inland	Total	Marine	Inland	Total	
	Fish	Other	Total						
2000	441634	18831	460521	42824	**503345**	35646	43385	**79031**	**582376**
2001	464987	19230	484410	43323	**527733**	29730	37514	**67244**	**594977**
2002	493446	29298	522744	43938	**566682**	26868	34297	**61165**	**627847**
2003	416126	46948	463074	44698	**507772**	39726	40217	**79943**	**587715**
2004	456752	48145	504897	45585	**550482**	49895	44115	**94010**	**644492**
2005	334248	46133	380381	46115	**426496**	69673	48604	**118277**	**544773**
2006	409945	79021	488966	44082	**533048**	72249	56694	**128943**	**661991**
2007	518201	70928	589129	43321	**632450**	80840	59033	**139873**	**772323**
2008	395660	57453	453113	41011	**494124**	85629	66557	**152186**	**646310**
2009	380636	44410	425275	39187	**464462**	82481	76248	**158729**	**623191**
2010	399656	46024	445680	40259	**485939**	88573	78568	**167141**	**653080**
2011	432246	45412	477658	37097	**514755**	88344	100446	**188790**	**703545**
2012	315637	80686	396322	36120	**432442**	10.853	111557	**212410**	**644852**
2013	295168	43879	339047	35074	**374121**	11.375	123019	**233394**	**607515**
2014	231058	35019	266078	36134	**302212**	12.894	108239	**235133**	**537345**

Between 1953 and 1958, total national fishery landings ranged from 100000 to 140000 tons (Üstündağ, 2010). In the following years, yields from capture fisheries showed a steady increase until 1998, as a result of state-led investments in fisheries during the 1980s. The highest capture fisheries production was in 1988 with a total of 623404 tons (TUIK, 2013). However, in the late 1980s a major collapse in marine capture fisheries production took place in the Black Sea, due mainly to overfishing and increased eutrophication (Düzgüneş *et al.,* 2014). As a result, capture fishery production dropped from almost 500000 tons in 1988 to 190000 tons in 1991. This collapse of fishery resulted in a shift in target fisheries from small pelagics to demersal fish in the Black Sea, which in turn, resulted in a decline in catches of demersal fish species (Ulman *et al.,* 2013). Many bottom trawl vessels, after experiencing low catches throughout the 1990s, switched their target fishery again from demersal fish to small pelagics such as sprat (Ulman *et al.,* 2013). During 1992-1995, capture fishery production recovered and landings reached the levels close to those recorded before 1988. However, in the following years capture fishery production began to decrease again. Data indicate that capture fishery production in 2013 and 2014 were, 295168 and 266078 tons, respectively (TUIK, 2013; BSGM, 2015; Table 4, 5).

Table 5. Capture marine fish production according to the regions (tons) (TUIK, 2013)

Years	Eastern Black Sea	Western Black Sea	Sea of Marmara	Aegean Sea	Mediterranean	Total
2002	251818	130229	68047	32559	10793	493446
2003	204754	107132	60925	31483	11832	416126
2004	233084	118129	60640	33946	10953	456752
2005	170841	63132	44768	38774	16733	334248
2006	229874	50640	67153	47680	14598	409945
2007	341188	71441	44447	44386	16739	518201
2008	283991	23123	38402	32870	17274	395660
2009	239703	38000	31709	44801	26423	380636
2010	255570	48121	36529	34996	24440	399656
2011	293263	40608	36433	31330	30613	432246
2012	157044	53556	45371	34784	24883	315637
2013	166205	43105	38284	30143	17431	295168

The Black Sea is the most productive area and provides approximately 71% (56% Eastern Black Sea, 15% Western Black Sea) of the marine capture fish production in Turkey (TUIK, 2013). The Sea of Marmara provides 13% of the production but has higher species richness of demersal and pelagic fish species than those of the Black Sea. The Mediterranean is the least productive sea with a share correponding to only 6% of total production. Capture fishery production in the Aegean Sea correponds to 10% of the total production. Although the Aegean Sea has many gulfs and bays, fisheries activities are limited due to the narrow continental shelf (Kınacıgil and İlkyaz, 2012). Anchovy, horse-chub mackerel, sprat, blue fish, bonito, whiting, sardines, red mullet, European hake and striped red species make up more than 90% of the total capture production in Turkey (Figure2). The major fish species in the national catch (2014) are anchovy (96440 ton), red mullets (1461 ton), horse mackerel (16324 ton), hake (642 ton), whiting (9555 ton), sardines (18077 ton), bonito (19032 ton), bluefish (8386 ton) and sprat (41648 ton) (BSGM, 2015).

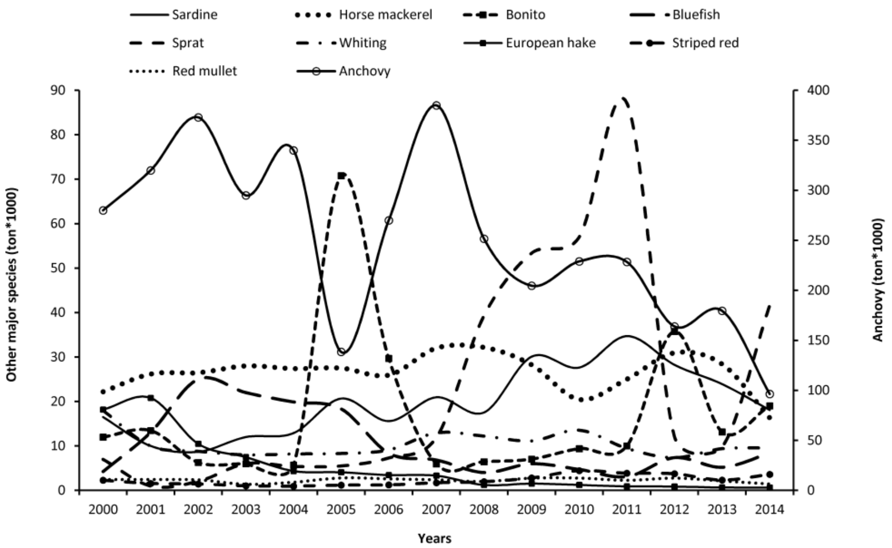

Figure 2. Catch of the major fish species in Turkey (BSGM, 2015)

Yields from demersal fishery resources correspond to about 18% of the annual total marine fisheries production between1985-2009. During 2010-2014, the share of demersal fishery production was similar and ranged between 14.8-26.3%. The maximum yield was in 1998 with 66500 tons (Tıraşın and Ünlüoğlu, 2012). In the following years, a noticeble declining trend in the annual total catch levels of demersal fisheries was recorded. In 2014, total demersal bony fish production was 21918 tons (BSGM, 2015).

In the Aegean Sea, demersal fishery landings amounts to 10000 tons/year, corresponding to about 31% of total demersal fisheries production. The demersal bony fish catches in the Aegean Sea began to increase in 1985 and attained two peaks of above 19000 tons in 1994 and 1998. Similar to the pattern observed in total capture fishery production, demersal bony fish landings began to decline in subsequent years. In 2003, the demersal capture production was less than 4000 tons. Despite a noticeble rise in 2006 (8500 tons), demersal production did not recover in the Aegean Sea; in 2013, demersal capture fish production was 5300 tons (TUIK, 2013).

With regard to species composition, 4 specieshake, red mullet, seabass and seabream made up about 50% of the total demersal fish landings in the Aegean Sea. Variations in the total landings of these four important demersal fish species over the period 1985-2009 is explained below. Hake was the most abundant fish species and contributed to 22% of the total demersal fish landings. Hake production increased to the historical maximum of 9100 tons in 1998 and declined steadily reaching 454 tons (8.5%) in 2013 (TUIK, 2013). Red mullets composed about 11% of the total demersal catch with a reported maximum landing of 2700 tonnes in 1994. The most recent data indicate red mullet landings amount to 534 tonnes, corresponding 10% of the reported demersal landings in 2013. Seabass is also an important target of the demersal fisheries constituting an average of 8% to the annual total demersal fish catches in the region. Seabass landings increased gradually from 28 tons in 1985 to a historical maximum of 3 500 tons in 1999. The reported seabass landing was only 120 tonnes in 2013 (2.2% of total demersal catch). Another important species targeted by demersal fisheries in the Aegean Sea is the seabream. Seabream comprised, on average, nearly 7% of the annual total demersal fish production in the region. Similar to seabass landings, the highest seabream landing was in 1999 with 1600 tons. Seabream landings decreased over time and in 2013, reported landing of seabream was 120 tons (2%) (Tıraşın and Ünlüoğlu, 2012; TUIK, 2013).

Molluscs are extensively exploited by demersal fisheries in the Aegean Sea. Octopus was the most dominant and commercially important cephalopod species during 1985-2009 periodand composed 19% of the annual total demersal invertebrate landings in the region. Octopus catches reached a peak in 1989 with 1600 tons. Octopus landings fell rapidly after 2000, reaching 540 tons in 2009 and 220 tons in 2013 (12.3%). Mediterranean mussel, which is the only bivalve species that are consumed locally, was the second most targeted species. This bivalve made up, on average, approximately 18% of the demersal invertebrate catches in the Aegean Sea. The highest reported Mediterranean mussel landing in the Aegean Sea was 9200 tons in 2006. Mediterranean mussel landings fell rapidly; reported landing in 2013 was only 41 tons (2.3%) (Tıraşın and Ünlüoğlu, 2012; TUIK, 2013).

Shrimps were the next most copious invertebrate group in the Aegean Sea demersal fisheries with landings corresponding to 15% of total invertebrate catch. The highest recorded yield was 1800 tons in 2005. Cuttlefish and squid followed shrimps in terms of abundance (2.3 and 3.4 thousand tons, respectively) both with similar average shares of around 12% of total demersal invertebrate landings. The highest yields for both species were recorded in the 1989. Shrimps, cuttlefish and squid collectively accounted for 72% of the total yield of demersal invertebrates in 2013 with corresponding amounts of 769.7, 267.5 and 251.7 tons, respectively (Tıraşın and Ünlüoğlu, 2012; TUIK, 2013).

The most recent data indicate that major pelagic fish species targeted in the Aegean Sea based on their landings are pilchard (31.2%), anchovy (27.9%), bogue (5.5%), Chup mackerel (4.9%), horse mackerel-scad (4.4%) grey mullet (2.6%), Atlantic bonito (2.4%) and bluefish (1%), respectively (Table 6). These species composed 86% of the total marine fish landings in the Aegean Sea. In addition, little tunny, tuna and sword fish are commercially important species targeted by pelagic fisheries. The most abundant fish species caught by demersal fisheries in the Aegean

Sea are red mullet-golden banded (1.6%), hake-European hake (1.5%), striped red (1.1%), whiting (0.7%), common sole (0.4%) and angler fish (0.4%), respectively (Table 6) (TUIK, 2013).

Table 6. The major fish landings and their respective ratios to the total marine fish production in the Aegean Sea, 2013.

Pelagic Species	Catch (ton)		Ratio %
	Turkey	Aegean Sea	
Anchovy	179615	8407	27,9
Pilchard	23919	9415	31,2
Horse mackerel-Scad	28424	1332	4,4
Atlantic bonito	13158	732	2,4
Bluefish	5225	309	1,0
Sprat	9764	-	0,0
Grey mullet	2505	773	2,6
Chup mackerel	2574	1479	4,9
Bogue	2226	1666	5,5
Demersal Species			
Whiting	9397	212	0,7
Hake-European Hake	676	454	1,5
Striped red	2333	344	1,1
Red mullet-goldon banded	2144	494	1,6
Turbot	209	1.4	0,0
Common sole	694	117	0,4
Angler fish	205	114	0,4
TOTAL	295168	30143	85,8

In recent years data indicate that the species composition of invertebrate landings has changed. Giant gamba prawn is the most widely captured (20.6%) species followed by deepwater rose prawn (19.2%), cuttle fish (14.9%), octopus (12.3%), squid (14.1%) and the Mediterranean mussel (2.3%). Landings of these six invertebrate species correspond to 83.4% of the total invertebrate production (Table 7) (TUIK, 2013).

Table 7. Invertebrate landings and their respective ratios to total invertebrate production in the Aegean Sea, 2013.

Species	Catch (ton)		Ratio %
	Turkey	Aegean Sea	
Giant gamba prawn	1364	370	20,6
Deep water rose prawn	1620	345	19,2
Cuttle fish	1244	268	14,9
Squid	491	252	14,1
Octopus	284	220	12,3
Mediterranean mussel	887	41	2,3
Other	37989	297	16,6

5. Discards

Bycatch of the non-target species is one of the serious problems due to illegal, unreported and unregulated fishing (Öztürk, 2014). Discards produced by trawl fishing account for over 20% of the total catch depending on the geographic area, depth, habitat type and season. However, Kelleher (2005) reported that trawl fisheries around Turkey have discard rates 45-50%. Discard rates between gear types are reported as<15% for artisanal fisheries, 5.1% for mid-water trawlers targeting small pelagics,11.5%for sea snail dredge fishery and 7.4% for coastal encircling nets (Kelleher, 2005). Very high discard rates were also reported; for example, Gökçe and Metin (2007) reported 77% discards from the commercial prawn trammel net fishery in the Aegean Sea. Similarly, İlker *et al.* (2008) reported 77.8% discard rate for monofilament nets and 22.8% for multifilament net fishing in the gillnet fishery in the Turkish Aegean Sea. Gurbet *et al.* (2013) reported 30.4% discards from demersal trawling in the İzmir Bay, the Aegean Sea. Keskin *et al.* (2014) reported 33% discards from demersal trawling around Gökçeada Island, the northeastern Aegean Sea. These are similar to Özbilgin *et al.* (2006) who reported 37% discards in demersal trawling in Turkish waters. Bycatch fish are not always discarded; Keskin *et al.* (2014) reported that while 49 species were always discarded, 32 species appeared in both the landed and discarded fractions. Reported discard rates by species are 30% for Mediterranean horse mackerel 25% for red mullet, 20% for Atlantic horse mackerel, 20% for shrimps, 5% for sharks 1%sea snails and 0.1% for turbot.

6. Fishing Regulations

Legislations pertaining to commercial fisheries in Turkey are regulated in the circular published by the Ministry of Food, Agriculture and Livestock. The current fishing regulations in Turkey include minimum mesh size and landing sizes; closed areas and seasons; gear or fishing method restrictions and bans and catch prohibition for some species. Fishing effort is regulated by system of vessel licensing (Keskin *et al.*, 2014, Özdemir, 2014). Currently, fisheries regulations are subject to continuous revisions when necessary based on feedbacks from research institutes, universities, local fisheries cooperatives, and other sectoral partners.

Restrictions for trawl fisheries include strict no-take zones, seasons, distance from land, and the shape and size of mesh in the codend. Saros Bay, Edremit Bay, Dikili Bay, Çandarlı Bay, İzmir Bay, Ildır Bay, Sığacık Bay, Kuşadası Bay, Yeşilova Bay, Hisarönü Bay, Güllük Bay, Gökova Bay and Köyçeğiz Port have been declared as restricted areas for trawling. Demersal trawls can only be towed by a single boat. In Turkish territorial waters, trawling is not allowed between April 15th and September 15th in order to protect the recruitment of demersal fish species. During the closed season, trawl vessels are allowed to continue fishing with special work permission in the international watersfor 2 months between July 15 – September 5 (Tokaç *et al*. 2010). Bottom trawling activities are banned within 1.5 miles of the Aegean Sea coasts of Turkey except Bozcaada Island (3 miles), the south coast of Gökçeada Island (3 miles), Tavşan Island-Zeytin Burnu (200 m) (between 39°39.572'N-27°00.058'E and 37°41.256'N-27°03.930'E), Sığacık Teke Burnu-Çeşme Burnu (3 miles) (between 38°06.356'N-26°35.620'E and 38°15.955'N-26°14.373'E), Boztepe Burnu (40°37.140'N-26°04.403'E) - Meriç River (3 miles). Fishing with trawlers is prohibited beyond 1000 m depth. Mesh size of cod-end in trawl nets should be 44 mm for diamond shape mesh or 40 mm for square shape mesh.

In Turkish territorial waters, purse siene fishery is prohibited from April 15th to August 31st. Use of nets with a depth >90 fathoms (164 m) is also prohibited (except for tuna fishing) In purse seine fishery, fishing in waters shallower than 22 m is also prohibited. In areas where light fishing is permitted, total lighting power of the main boat, accompanying boat and carrier boat can not exceed 8000 watts. A minimum of 200 m distance should remain between the lighting boats of two different teams. In the territorial waters, light fishing is banned in areas shallower than 30 m, i.e. Güllük Bay, Asin Bay, Ildır Bay, İzmir Bay, Çandarlı Bay, Küçükkuyu port and Saros Bay in the Aegean Sea. In the territorial waters, tuna fishing by purse seine between July16 and August 15 is prohibited.

It is prohibited to use hooks smaller than number 14 (smaller than 7.2 mm) in longline fishing. Mesh size of trammel nets shall not be larger than 36 mm beginning September 01,2016. The use of beach seine, beam trawl and drift net for any type of fishing and monofilament gillnets are not allowed in the Aegean Sea.

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ICHTHYOPLANKTON OF THE AEGEAN SEA

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1. Introduction

The life cycle of fish consists of five periods which are embryonic, larval, juvenile, adult and senescent (Fuiman and Werner, 2002). The kind of the plankton that contains the fish eggs and larvae is studied under the name of "ichthyoplankton". In their trophodynamic interactions, the fish eggs and larvae are exposed to the predation of several pelagic invertebrates (for instance; Chaetognatha, Ctenophora, Medusae, Euphasida, Copepoda, Amphipoda, Dinophyceae), planktivorous fish (for instance; anchovy, pilchard) and larvae (for instance; *Scomberomorus* sp.) at the beginning of their nutrition (Shoji and Tanaka, 2001, Fuiman and Werner, 2002). The hatched fish larvae struggle to have the edge over to be bigger, to survive and for recruitment, by living on smaller planktons. This nutritional dynamism indicates, to what extend the abiotic and biotic factors and the distribution and abundance of ichthyoplanktons, the recruitment of fish larvae and its mortality interact with each other. Besides, the researches on ichthyoplankton are significant in three working fields in fisheries method related to ichthyoplankton. Moreover, the problems related to early life phases are part of these three fields (Royce, 1972). They are as follows:
1-Management of public fishing resources
2-Protection and enhancement of the environmental conditions
3-Aquaculture

Through the analysis of species identification from the eggs and larvae of fish for management of fishing resources and shores, spawning time, spawning area and density, estimation of spawning mature stock, survival rate of the new generation and affecting factors, it is possible to make a general evaluation of fish resources over ichthyoplankton. In aquaculture, in which the life cycle is under control with the aim of increasing the fish population both in trade and nature, it is quite important to know well the eggs and larvae of fish species.

Aegean Sea is suitable for the nutrition and breeding of fish species due to the mix of two water bodies of different characteristics; one of which, coming from North-East through the Dardanelles to Black Sea, is cold, has low salinity and rich with nutrients and the other, coming from Mediterranean, has higher salinity and temperature

(Artuz and Korkmaz, 1976). In the aspect of variety and abundance of both pelagic and demersal fish species, Aegean Sea is quite significant because of the concavity in the middle of it, that its continental shelf contains rough and wide plains and as it is the migration route of fish. Therefore, 10.2% of fishing in Turkey comes from Aegean Sea (TUIK, 2013).

The ichthyoplankton researches in Aegean Sea are focused especially around Bay of Izmir and there are many researches available on eggs and larvae of bony fish species. The first research has been done by Demir (1959) and followed by Mater (1977, 1978, 1979, 1980, 1981, 1983), Mater and Yalcın (1985), Mater *et al.* (1990), Mater and Coker (2002), Cihangir (1995), Hossucu (1991, 1992a, 1992b), Hossucu and Mater (1995), Hossucu and Ak (2000, 2002), Turker Cakır *et al*. (2005), Taylan and Hossucu (2008, 2011, 2015). In Bay of Edremit, Turker Cakır (2004), Turker Cakır *et al*. (2008b), in Bay of Candarlı Ak Orek *et al.* (2005), at the shores of Yeni Sakran Coker *et al.* (2012) have carried out researches.

2. Sampling processing of Ichthyoplankton

In Aegean Sea, during the ichthyoplankton researches, after the identification of the research area, stations are determined on the map of the territory through quadrature. The plankton draughting is done vertically, horizontally or oblique by expediently using plankton dip nets like Hensen tip, WP-2 model, Bongo net. During the draughting, equipment like CTD (conductivity, temperature and depth monitor) for the analysis of water samples and flowmeter to determine the amount of drainage water are used. The sample of plankton that is collected is stored in the sample jars which contain formalin solution buffered with 5% borax and is brought to the laboratory. Primarily, the eggs and larvae of fish are separated from other zooplankton and identified in the laboratory. The density of the eggs and larvae that are identified is given as the number of individuals per cubic meter (n/m^3) for horizontal draughting and as the number of individuals per square meter (n/m^2) for vertical draughting (Ozel 1992).

3. Identification Criteria for Eggs and Larvae

The egg and larva measurements are done by using micrometric ocular in binocular stereoscopic. Besides the pigmentation on the vitellus, oil drop and embryo; diameter of the egg, perivitelline space, oil drop site, number and diameter, structure of the vitellus, if there is a pattern etc. on the egg membrane or not are important in identification of eggs. The morphometric larva length (the length from the tip of the nose, along the lateral of the body to the urostyle or hypural), preanal lenght, head height and length, eye diameter, body height measurements in line with pectoral fin and the numbers of myomere of larva are studied out. Pigmentation is also quite important in larva identification.

4. Diversity and Abundance of Ichthyoplankton in Aegean Sea

Respectively from North to South, the most important fishing areas of Aegean Sea are Bay of Saroz, around Gökçeada and Bozcaada, Edremit, Candarlı, Izmir, Sıgacık, Bay of Kusadası, Kovela harbour, Bay of Gulluk, Bay of Gokova. When the ichthyoplankton researches that have been carried out in Aegean Sea are analyzed, it is clear that those researches are quite weak and they have been focused just on specific areas. As a result of the researches carried out in Bay of Izmir from 1974 to 2005, 144 species (Coker and Mater 2006), in Bay of Edremit, 62 species (Turker Cakır 2004), in Bay of Candarlı, 43 species (Ak Orek *et al.* 2005) have been identified. Having identified 45 species of 27 families as a result of the plankton draughting that they have done in 24 stations in their research which includes Bay of Saros, Edremit, Candarlı and Izmir, Turker Cakır *et al.* (2008b) have found out that especially the Engraulidae, Clupeidae and Sparidae families are dominant. In addition to that, in Bay of Edremit (Turker Cakır and Hossucu, 2006; Turker Cakır *et al.* 2008a), in Bay of İzmir (Taylan and Hossucu, 2008, 2011, 2015) they have found out that the eggs and larvae of Engraulidae and Clupeidae families are dominant. In the research they have carried out in Foca (Izmir), Bay of Edremit, Bay of Saros and North of Gokceada, Gokturk *et al.* (2008) have stated these areas to be the main spawning ground of anchovy. According to Mater and Coker (2002) the species that are identified in Aegean Sea and their spawning periods are as in Table 1.

Table 1. The spawning periods of some species identified in Aegean Sea (Mater and Coker 2002)*.

Species	Area	Author	Spawning periods
Fam: Clupeidae			
Sardina pilchardus	Izmir Bay	Mater	November-May
	Izmir Bay	Hossucu	October-March
	Edremit Bay	Türker	October-May
Sardinella aurita	Izmir Bay	Mater	May-October
	Izmir Bay	Yalcın	June
	Izmir Bay	Hossucu	May-October
Sprattus sprattus	Izmir Bay	Mater	March
Fam: Engraulidae			
Engraulis encrasicolus	Izmir Bay	Mater	March-November
	Izmir Bay	Hossucu	March-September
Fam: Sternoptychidae			
Maurolicus müelleri	Saroz/Gokova	Coker	February
Fam: Photichthyidae			
Vinciguerra attenuata	Gokova	Coker	February
Fam: Argentinidae			
Argentina sphyraena	Saroz/Gokova	Coker	February
Fam: Synodontidae			
Synodus saurus	Izmir Bay	Mater	May-August
Fam: Myctophidae			
Lobianchia dofleini	Gokova	Coker	February
Fam: Congridae			
Ariosoma balearicum	Bodrum-Yalıkavak	Coker	October

Fam: Exocoetidae			
Hirundichthyes rondeletii	Aegean Sea	Coker	September
Fam: Macrorhamphosidae			
Macrorhamphosus scolopax	Aegean Sea	Coker	April
Fam: Syngnathidae			
Syngnathus acus	Izmir Bay	Coker	February-November
Fam: Merlucciidae			
Merluccius merluccius	Aegean Sea	Coker	February
	Izmir Bay	Coker	March-November
Fam: Gadidae			
Gadiculus argenteus argenteus	Saroz/Gokova	Coker	February
Micromesistius poutassou	Gokova	Coker	February
Trisopterus minutus capelanus	Izmir Bay	Mater	February -March
Phycis blennoides	Saroz	Coker	February
	Izmir Bay	Coker	April
Fam: Zeidae			
Zeus faber	Aegean Sea	Coker	April-May
Fam: Serranidae			
Serranus cabrilla	Izmir Bay	Mater	April-August
	Izmir Bay	Ak	April-August
Serranus scriba	Izmir Bay	Mater	May-August
	Izmir Bay	Ak	April-August
Serranus hepatus	Izmir Bay	Mater	April-August
	Izmir Bay	Ak	April-September
Fam: Moronidae			
Dicentrarchus labrax	Izmir Bay	Mater	February-April
	Izmir Bay	Ak	January-March
Fam: Cepolidae			
Cepola rubescens	Izmir Bay	Ak	October
	Izmir Bay	Coker	September-November
Fam: Carangidae			
Naucrates ductor	Bodrum-Yalıkavak	Coker	October
Trachurus mediterraneus	Izmir Bay	Mater	March-July
	Izmir Bay	Ak	May-August
Trachurus trachurus	Izmir Bay	Mater	May-August
	Izmir Bay	Ak	May-September
Fam: Mullidae			
Mullus barbatus	Izmir Bay	Mater	March-August
	Izmir Bay	Ak	April-September
Mullus surmuletus	Izmir Bay	Mater	March-April
	Izmir Bay	Ak	May-June
Fam: Sparidae			
Diplodus annularis	Izmir Bay	Mater	March-July
	Izmir Bay	Ak	March-August
Diplodus sargus	Izmir Bay	Ak	June
Lithognathus mormyrus	Izmir Bay	Mater	June-August
Pagellus bogaraveo	Izmir Bay	Ak	October
Pagellus erythrinus	Izmir Bay	Ak	May-September
Sparus aurata	Izmir Bay	Mater	November-February
	Izmir Bay	Ak	November-February
Fam: Centracanthidae			
Spicara maena	Izmir Bay	Ak	September-November
Fam: Labridae			
Coris julis	Izmir Bay	Mater	May-August
	Izmir Bay	Ak	April-September
	Izmir Bay	Coker	March-September
Symphodus melops	Izmir Bay	Ak	May-June
Thalassoma pavo	Izmir Bay	Ak	August
Fam: Ammodytidae			
Gymnoammodytes cicerellus	Izmir Bay	Coker	June

Fam: Trachinidae			
Echiichthys vipera	Izmir Bay	Mater	February-March
	Izmir Bay	Ak	January-September
Trachinus draco	İzmir Bay	Ak	June-August
Fam: Trichiuridae			
Lepidopus caudatus	Saroz/Gokova	Coker	February
Fam: Scombridae			
Sarda sarda	Izmir Bay	Ak	September
Scomber japonicus	Izmir Bay	Mater	June-August
	Izmir Bay	Ak	Winter-Spring
Scomber scombrus	Izmir Bay	Mater	May
	Izmir Bay	Ak	May
Fam: Xiphiidae			
Xiphias gladius	Aegean Sea	Demir	May
Fam: Gobiidae			
Gobius niger	Izmir Bay	Ak	April-October
	Izmir Bay	Coker	April-October
Gobius paganellus	Izmir Bay	Ak	April-October
	Cesme	Coker	February
	Izmir Bay	Coker	April-January
Pomatoschistus minutus	Izmir Bay	Ak	March-October
	Izmir Bay	Coker	April-February
Pomatoschistus microps	Izmir Bay	Coker	March-July
Fam: Callionymidae			
Callionymus lyra	Izmir Bay	Coker	March-November
Callionymus maculatus	Izmir Bay	Mater	May
Callinymus pusillus	Izmir Bay	Mater	March-September
	Izmir Bay	Ak	March-September
Fam: Blenniidae			
Blennius ocellaris	Izmir Bay	Mater	May-August
	Izmir Bay	Coker	April-May
Lipophrys pavo	Izmir Bay	Coker	April-August
Parablennius gattorugine	Izmir Bay	Coker	March-October
Parablennius sanguinolentus	Izmir Bay	Coker	April-May
Parablennius tentacularis	Izmir Bay	Coker	April-August
Fam: Carapidae			
Carapus acus	Izmir Bay	Mater	May
Fam: Centroelophid			
Centrolophus niger	Dardanelles/ Saroz	Coker	February
Fam: Sphyraenidae			
Sphyraena sphyraena	Izmir Bay	Mater	May-August
	Izmir Bay	Ak	October
Fam: Mugilide			
Liza aurata	Izmir Bay	Ak	December-February
Liza saliens	Izmir Bay	Mater	May-August
	Izmir Bay	Ak	May-June
Mugil cephalus	Izmir Bay	Mater	August
	Izmir Bay	Ak	June-October
Fam: Atherinidae			
Atherina hepsetus	Izmir Bay	Mater	April-August
Atherina boyeri	Izmir Bay	Ak	March-May
Fam: Scorpaenidae			
Helicolenus dactylopterus	Izmir Bay	Coker	April
Scorpaena porcus	Izmir Bay	Mater	March-August
Scorpaena scrofa	Izmir Bay	Mater	February-December

Fam: Triglidae			
Lepidotrigla cavillone	Izmir Bay	Mater	March
Trigla lucerna	Izmir Bay	Mater	December-March
Fam: Scophthalmidae			
Psetta maxima	Izmir Bay	Mater	May-June
Fam: Bothidae			
Arnoglossus laterna	Izmir Bay	Ak	April
Arnoglossus thori	Izmir Bay	Coker	March-July
Fam: Pleuronectidae			
Platichthys flesus luscus	Izmir Bay	Ak	January-April
Fam: Soleidae			
Buglossidium luteum	Izmir Bay	Mater	January-September
	Izmir Bay	Ak	January-September
	Izmir Bay	Coker	January-November
Microchirus variegatus	Izmir Bay	Mater	February-March
Solea lascaris	Izmir Bay	Ak	December-January
Solea vulgaris	Izmir Bay	Mater	December-April
	Izmir Bay	Hossucu	December-March
	Izmir Bay	Ucal	March
Fam: Gobioesocidae			
Lepadogaster candollei	Cesme-Alacatı	Coker	August

* *The species are indicated only belong to Aegean Sea*

As the researches carried out on ichthyoplankton in Aegean Sea are observed more densely and regularly especially in the Bay of Izmir than the other researches, the diversity of species of eggs and larvae of species that are identified in this territory have been given on the basis of family (Figure 1, Figure 2) (DBTE, 2009-2014). It has been found out that among both the eggs and the larvae, the species of *Engraulis encrasicolus* (Engraulidae) is the most dominant and is followed by *Sardina pilchardus* (Clupeidae).

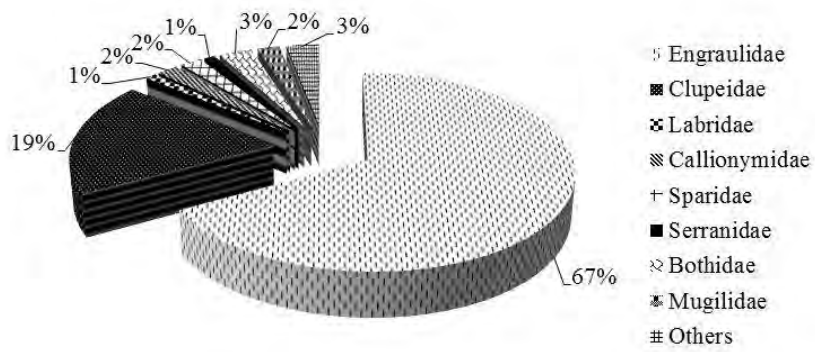

Figure 1. The distribution % of the eggs that were identified in the Bay of Izmir from 2009 to 2014, on the basis of families.

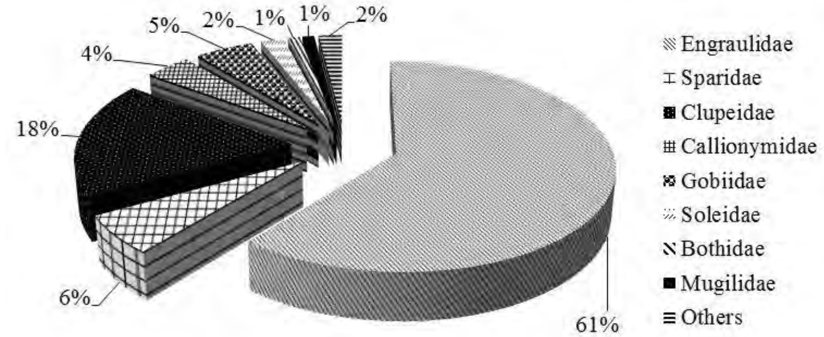

Figure 2. The distribution % of the larvae that were identified in the Bay of Izmir from 2009 to 2014, on the basis of families.

When the abundance of the eggs and larvae of *E. encrasicolus* and *S. pilchardus* that are densely available in the Bay are examined based on years; while there is similarity in anchovy, there are remarkable ups and downs in pilchards (Figure 3, Figure 4). Nevertheless, when the reports of TUIK (Turkish Statistical Institute) (2009-2013) are analyzed; it has been found out that the amount of pilchard fishing in Aegean Sea shows a difference in line with the abundance of the eggs and larvae.

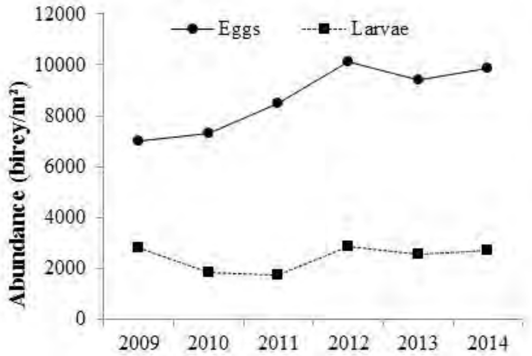

Figure 3. The abundance of the eggs and larvae of *Engraulis encrasicolus* by years in Bay of Izmir (individual/m^2)

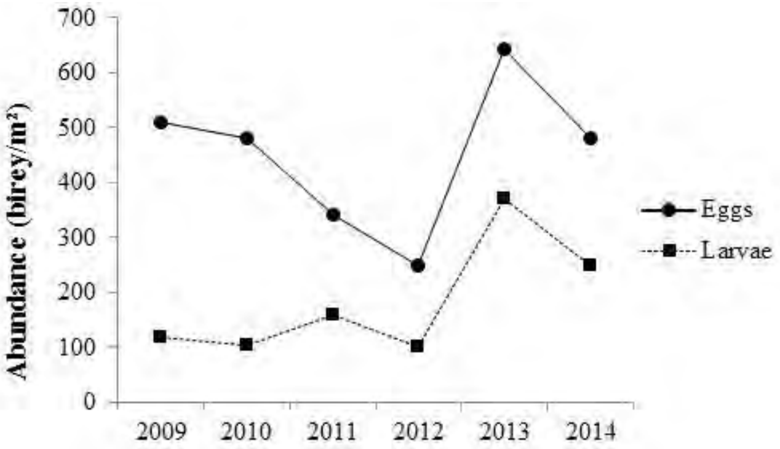

Figure 4. The abundance of the eggs and larvae of *Sardina pilchardus* by years in Bay of Izmir (individual/ m^2)

When the abundance and distribution of the sum of eggs and larva that were identified from 2009 to 2014 are analyzed; it has been found out that both eggs and larvae are more densely available in the outer sites of the bay where it is cleaner than the inner bay (Figure 5, Figure 6). The reason for this is supposed to be the cyclonic flow system all around the bay. The reason why the abundance of the eggs come out to be more in the inner bay is anchovy and the eggs of anchovy are known to be tolerant to pollution.

In Aegean Sea where the 10.2% of the fishing in Turkey is, the 31% of the total fishing is pilchard, 27.9% of it is anchovy (TUIK 2013). During the ichthyoplankton researches which have been carried out in line with this; that anchovy and pilchard show a similarity in abundance and variety of species of eggs and larvae that have been identified, is the proof of that. In the shores of Turkey, in terms of the estimation, sustainability and management of the stocks of these species, detailed researches need to be carried out. With this aim, in addition to the ichthyoplankton researches, Daily Egg Production Method (DEPM), which is used in the estimation of pelagic fish stocks, must be carried out alongside. As there is just a single research that was carried out in Bay of Edremit (Taylan 2014) available about this issue, it is regarded that these kind of researches must be frequently carried out all around Aegean Sea in the future. As a result, healthier data can be gathered about pelagic fish stocks along the Turkey shores of Aegean Sea.

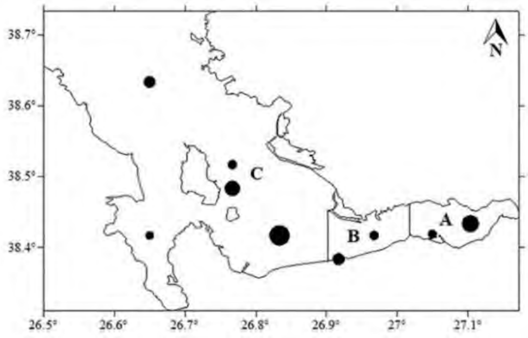

Figure 5. The abundance and distribution of the eggs that were identified from 2009 to 2014 in Bay of Izmir (A: inner bay, B: middle bay, C: outer bay)

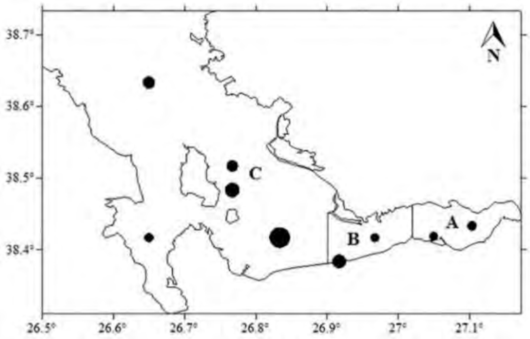

Figure 6. The abundance and distribution of the larvae that were identified from 2009 to 2014 in Bay of Izmir (A: inner bay, B: middle bay, C: outer bay)

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AN OVERVIEW OF HIGH SEAS FISHERY IN THE AEGEAN SEA

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1. Introduction

United Nations Food and Agriculture Organization (FAO) defines high seas fisheries as "High seas fisheries refers to those resources distributed exclusively in the high seas, *i.e.* in waters beyond the areas of national jurisdiction (which can be 200 nautical miles or less) excluding species fixed on the continental shelf which remain under the sovereign rights of the coastal States". This fisheries exploits high seas resources, *i.e.* stocks living permanently in high seas, highly migratory resources (when they are out of any national jurisdiction), or high seas portions or life stages of straddling stocks (FAO, 2015). The term "high seas" has been defined as "international waters" in the fisheries glossary of GFCM (GFCM, 2015b). International fisheries, *i.e.* fisheries on the high seas outside the EEZs, isparticularly an area of challenge (Ridgeway, 2007).

Scientific studies concerning high seas fishery in the Aegean Sea have been limited. Öztürk *et al.* (2002) emphasizes that the importance and sharing of living marine resources issue has been the least minded among the Aegean Sea disputes.

Total Turkish marine fisheries production, excluding aquaculture, was 339,047 tons and Aegean Sea contributed 31,936 tons. In another word, 9 % of Turkey's marine production comes from the Aegean Sea. Despite that the catch of the Aegean Sea seems relatively low when compared to that of other seas surrounding Turkey, the economic value of the production is relatively high.

In terms of production amount, the main pelagic species are pilchard, anchovy, bogue, chup mackerel, scad, grey mullet, and atlantic bonito. Even though it seems not so productive in harvesting volume, the Aegean Sea is a very important fishing zone with its high grading species, providing food and income for coastal communities. The map showing Fisheries Statistical Regions for data gathering in the Aegean Sea is presented in Figure 1.

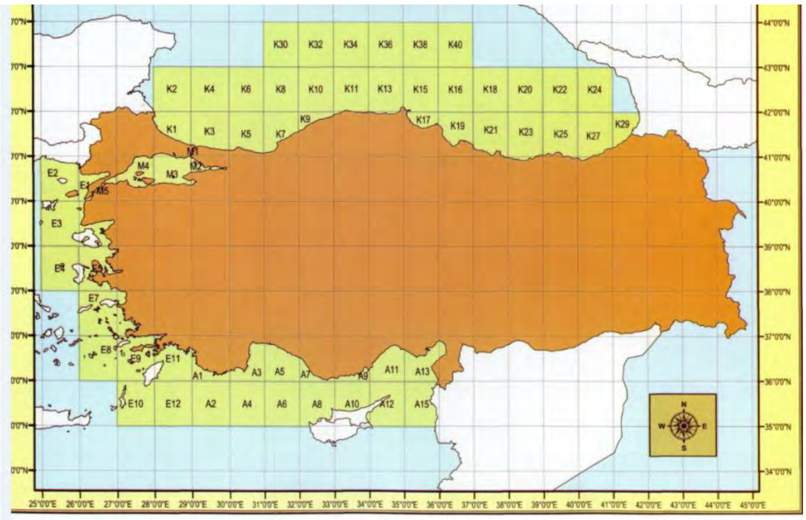

Figure 1. Fisheries Statistical Regions in Aegean Sea (MoFAL, 2006)

In 2014, 7509 fishermen engaged in fisheries in the Aegean region (TurkStat, 2014), inferring also it is one of the important sources of employment for the region. Ünal *et.al*. (2009) reported 57 fishery cooperatives which have 3256 members in the Aegean coast.

The number of vessels carrying out fishing activities in the Aegean Sea is 4509 and they comprise approximately 33 % of the total Turkish fishing fleet.

Kınacıgil and İlkyaz (1997; 2012) defined the main fishing areas as Saros Bay, Gökçeada and Bozcaada, Edremit Bay, Çandarlı Bay, İzmir Bay, Sığacık and Kuşadası Bay, Kovela Port, Güllük (Mandalya) Bay and Gökova (Kerme) Bay, from north to south in the Aegean Sea (Figure 2).

General Fisheries Commission for the Mediterranean (GFCM) reported the total catch obtained in the Aegean Sea as 82,292 tons in 2013, according to the data reported by the national authorities of countries to FAO/GFCM through the STATLANT 37A questionnaire. Total productions of Turkey and Greece in the Aegean Sea in 1970-2013 are shown in Figure 3 (GFCM, 2015a).

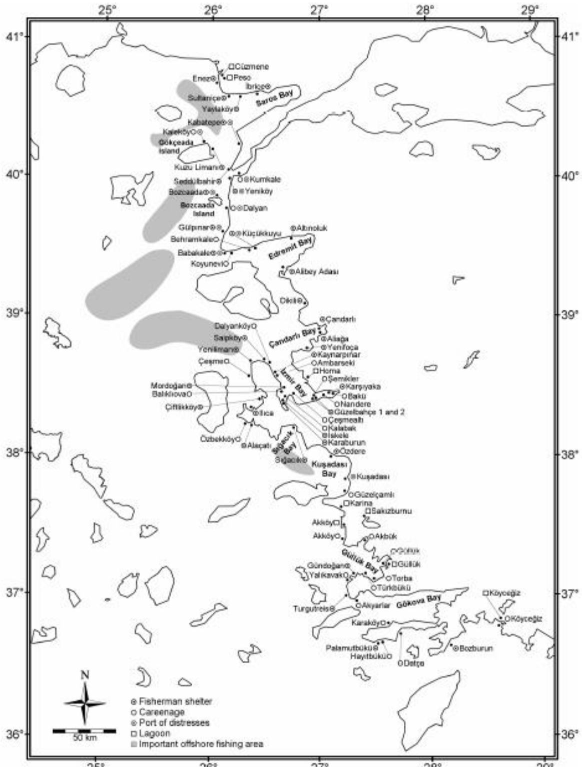

Figure 2. Fisherman shelters, careenages, port of distresses, lagoons and important offshore fishing areas of the Aegean Sea. (Kınacıgil and İlkyaz, 2012)

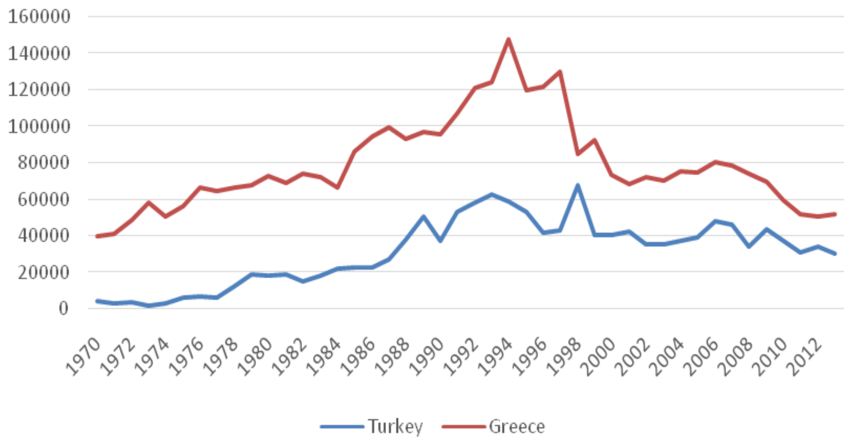

Figure 3. Productions (ton) of Turkey and Greece in the Aegean Sea in 1970-2013 (GFCM, 2015a)

It is clear that Turkey's production landed in the Aegean Sea increased significantly in the last 40 years and this increase indicates the increasing interest of Turkish fishermen in both coastal and high sea fisheries. TurkStat statistics also supports this trend as for the rising share of the Aegean Sea in total fisheries harvest of Turkey.

2. Legal Framework, Fisheries Management and Enforcement

Turkey is not a party to neither United Nations Convention on Law of the Sea (UNCLOS), nor 1958 Geneva Conventions and there is no obligation to comply with its provisions. On the other hand, Turkish fisheries management administration, Ministry of Food, Agriculture and Livestock (MoFAL), based on many years of experience and history, gives importance to the implementation of effective protection and control measures. Inspections and controls as performed according to applicable international and regional instruments as well as of relevant EU regulations are currently being voluntarily applied by Turkey.

Turkey has shown utmost importance to the achievement of shared aims of multilateral agreements and to the strengthening of further cooperation and collaboration among the member states for effective implementation of regulatory measures specified by the agreements (MoFAL, 2007)

The legal framework for fishing in the international waters has been drawn in Turkish national legislation. Turkish Fisheries Regulation 22223 of 1995, Fisheries Notifications for Commercial Fishing and Implementing Rules are the main regulatory instruments specifying the rules of fishing in the international waters for Turkish fishing fleet.

Within the scope of mentioned legal tools;

a. The Article 18 of Turkish Fisheries Regulation,

"Specifications such as; species, length and weight or catchable amounts and period of fishing in exclusive economic zones, the minimum qualities and conditions of gears, basis and principles of using them, and other conditions are determined by the Ministry.

It is obligatory to get permission from MoFAL for vessels if they are going to pass through the prohibited areas during the closed fishing season. This is done taking the measures mentioned in other laws.

and

b. The Article 46, (Par.4,5,6) of Notification 3/1 of (2012/65),

"*The species, variety, weight, size, catchable amounts and times of the fisheries to be harvested in the exclusive economic zone and the international waters, as well as the fundamental quality and conditions of the respective gears, procedures and principles of their use, and other activities shall be determined by the Ministry.*

The regulation for the territorial waters specified herein shall also be implemented in the neighboring exclusive economic area and the international waters, in case of no other relevant regulation is specified and announced by the Ministry.

Boats to sail through the prohibited zones at prohibited times for fishing in international waters shall comply with the principles adopted by the Ministry, except for the measures specified in the laws.

In accordance with this legal framework, an Implementation Circular Letter also has been issued yearly, which is specific to fishing in the international waters. Pursuant to this Circular Letter (MoFAL, 2015), both input and output control measures have been applied, such as fishing gear restrictions, landing sites, reporting and documentation (transport, origin, etc.) obligations. In the scope of fisheries management in international waters, the conservation measures applied for the territorial waters also valid for the neighboring exclusive economic zones and the international waters, unless specified otherwise and announced.

Turkish fisheries management authority (MoFAL) limits the number of ports where the operators/captains may land their catch in order to control the catches accurately. The fishing ports that are designated for landing for 2015 fishing season are listed in Table 1. Designated ports are compulsory for landing of fish caught in the international waters.

Table 1. Landing Ports in Aegean Sea for catches harvested in the international waters allowed by MoFAL (MoFAL, 2015).

District	Landing Ports
Edirne	Enez Port
Çanakkale	Yeniköy, Babakale, Kabatepe, Gürpınar, Uğurlu Fishing Ports
Izmir	Saipaltı, Dikili, Yeni Liman (Karaburun), Foça, Seferihisar Sığacık Fishing Ports
Aydın	Taşburun Fishing Port
Muğla	Bozburun, Datça, Fethiye, Marmaris, Yalıkavak Fishing Ports

3. Fishing by Turkish Fleet in the International Waters of Aegean Sea.

Turkish vessels engaged in fishing in the international waters of the Aegean Sea increased significantly in the last two decades. Tokaç *et al.* (2010b) drew attention to the fact that the international waters of the Aegean Sea have become popular fishing grounds for the relatively large and newly designed demersal trawlers in Turkey. According to the Fisheries Information System (FIS) database of MoFAL, the number of the vessels authorized for fishing in the international waters was 160 in 2014 (FIS Database), while it was only 65 in 1997 (Öztürk *et al.*, 2002). For the 2015 fishing season, 171 fishing vessels have been authorized. It is remarkable that the fleet size nearly tripled since 1997, with *volens et potens* fishermen.

Between 2010-2014, totally 866 fishing vessels have been authorized by MoFAL, to fish in the high seas. The lengths of the fishing vessels were between 12-45 meters.

The length of the fishing vessels varied between 12 and 45 meters and the majority of the fleet consists of vessel between 20-30 meters in length (Figure 4).

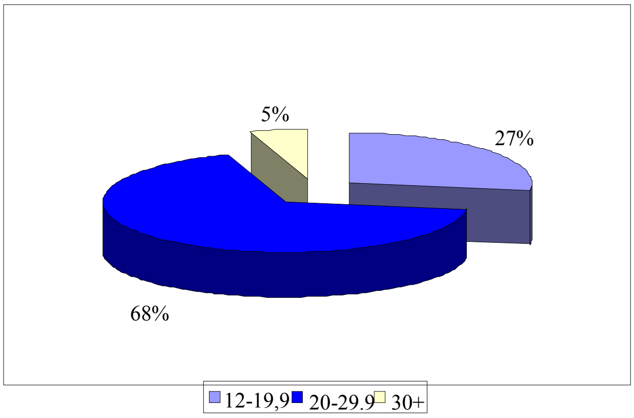

Figure 4. Length composition of vessels authorized to Ffsh in the international waters of the Aegean Sea (2010-2014). (MoFAL FIS Database, 2015)/

Öztürk *et al,* (2002), emphasize that all types of industrial fishing methods was applied by Turkish fishermen, while trawl vessels constitute the 67% of the fleet fishing in the high seas of Aegean Sea in the first row. Kınacıgil and İlkyaz (2012) reported 118 purse seiners and 188 trawlers certificated for fishing in international waters of the Aegean Sea, in 2010.

For the latest fishing seasons, since 2011 only trawl vessels has been allowed for fishing in the international waters of Aegean Sea.

Main fishing areas used by Turkish fishing fleet in the international waters of Aegean Sea has been submitted in Figure 5. (Öztürk *et al.,* 2002) and in Figure 6. (Kaykaç et.al.,2012).

Tokaç *et al.* (2010a, 2010b), Kaykaç *et al.* (2012) emphasized that in the period of seasonal closure for coastal trawling, fishing boats are allowed to work in the international waters with a special permit issued by the MoFAL.

4. Fisheries Management Enforcement

No serious infringement was detected, under the favor of highly discouraging and deterrent effect of sanctions (such as repealing the permits), strict patrolling of law enforcement agency and controls done at landing ports. Öztürk (2015), however, reported that IUU fishing issue should be monitored in terms of sustainable use of the stocks.

5. Conclusion

Marine living resources are diminishing in the Aegean and eastern Mediterranean Sea. Besides, marine biological diversity is facing various threats, such as overfishing, land-based and ship-originated pollution, exotic species and by-catch (Öztürk and Öztürk, 2003 ; Öztürk, 2009).

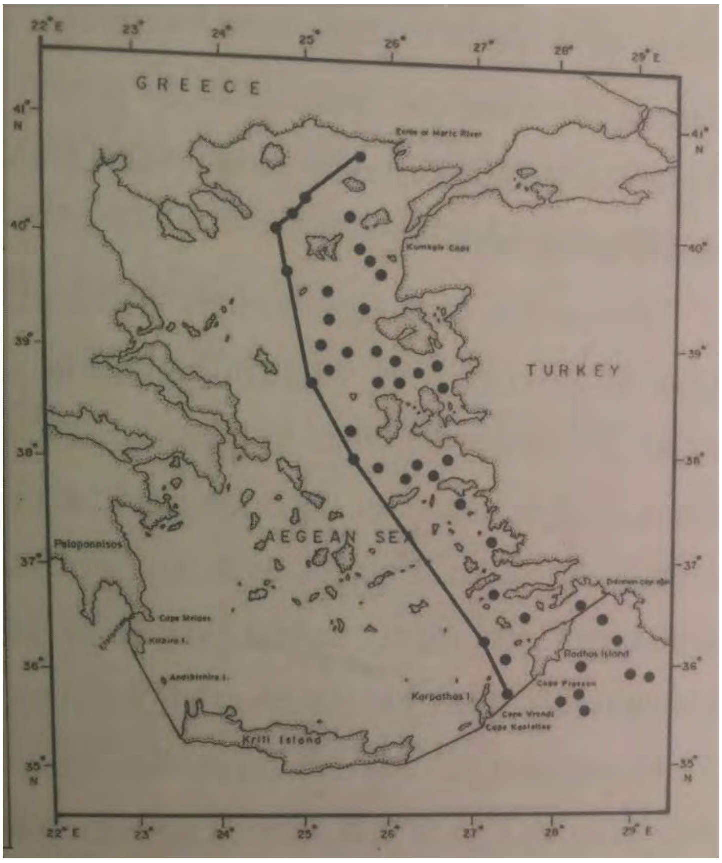

Figure 5. Fishing zones used by Turkish fishing fleet in the international waters of the Aegean Sea (Öztürk *et al.,* 2002)

Figure 6. International waters of the Aegean Sea where Turkish fishing fleet generally operate. (Kaykaç *et al*., 2012)

The effective management of fisheries is pivotal for the conservation of living marine resources, their sustainability and ecosystems both in national and international waters. It should also involve more stakeholders incorporating legal, socio-economic and policy dimensions.

With regard to the sustainable use and conservation of marine living resources of high seas, Turkey has given high importance to the UN Conference on Straddling Fish Stocks and plans to take into consideration the principles established by the Conference (Ünal and Göncüoğlu, 2012).

This study offers a general view for fisheries held by Turkish fishing fleet in the international waters of the Aegean Sea, in order to point out the importance and the necessity on the basis of cooperation and building strong partnership between states and encouraging fishers in order to promote international fisheries management. Besides, biletarel technical cooperation and exchange of information with Greece for fishing season, banned fish species, and sustainable fisheries of the resources in the international waters of the Aegean Sea is recommended.

Acknowledgment

Authors would like to thank distinguished colleagues Mr. Hamdi ARPA and Ms. Şule ŞUMLU for their invaluable contributions.

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THE STATE OF HIGHLY MIGRATORY BONY FISH SPECIES IN THE AEGEAN SEA

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1. Introduction

The Aegean Sea has significant importance for highly migratory fish species such as swordfish *Xiphias gladius* (Linnaeus, 1758), mediterranean spearfish *Tetrapterus belone* (Rafinesque, 1810), frigate tuna A*uxis thazard* (Lacepede, 1800), bullet tuna *Auxis rochei* (Risso, 1810), albacore *Thunnus alalunga* (Bonnaterre, 1788), atlantic saury *Scomberesox saurus* (Walbaum, 1792) and common dolphinfish *Coryphaena hippurus* (Linnaeus, 1758). In addition, these fish stocks are shared by Turkey and Greece and need to protect this vulnerable resource.

These fish species are caught by purse seine, gillnet, longline, harpoon and driftnet in the Turkish seas. Driftnets were prohibited in 2006 by the Turkish Ministry of Food, Agriculture and Livestock.

Xiphias gladius Linnaeus, 1758 – Swordfish

The swordfish is a pelagic and oceanic species which is found in the Pacific, Indian and Atlantic Ocean, including the Mediterranean Sea, the Sea of Marmara, the Black Sea, and the Sea of Azov.

Commercially the swordfish is one of the most valuable fishes in the basin. Swordfish are taken either as a commercial target, as bycatch in longline In the Aegean Sea, the main fishing method is longlining for swordfish fishery in Turkey. A few fishermen are still using the traditional method with harpoons for this species in Marmara Island and Gökçeada (Ceyhan and Akyol, 2009). However, some swordfish are also caught incidentally by purse seines as by-catch. About 150 vessels were involved in the swordfish fishery and most of them are smaller than 20 m in length (LOA) in Turkey in 2013(Anonymous, 2014).

The enforcement of a minimum landing size (MLS) for swordfish is 125 cm (LJFL), while Turkey has also implemented a closed fishing season from 15 February to

15 March and from 1 October to 30 November, and incidental catch rate of swordfish should not be greater than 5% in the number of the total catch (Anon, 2012). Swordfish has been listed as a least concern species, according to The World Conservation Union's "Red Data List" (IUCN, 2015).

It is a highly migratory species, yet these are solitary animals, rarely pairing except for spawning. Sexual maturity is thought to occur at 2-5 year of age in the Mediterranean Sea (De Metrio *et al*., 1989). Mediterranean Sea swordfish reach sexual maturity at about 125 cm and 142 cm for female (de la Serna *et al*., 1996; Di Natale *et al*., 2002) and 139.5 cm for Turkishs waters (Alıçlı *et al*., 2014).

In 2013, the seas in Turkey attributed with the highest catches were Mediterranean Sea (96.8 t), Aegean Sea (57.1 t) and Marmara Sea (3.6 t) and, to a lesser extent, western Black Sea (0.2 tons), (TURKSTAT, 2015). Percentage of Mediterranean countries in the total swordfish catch is shown in Figure 1.

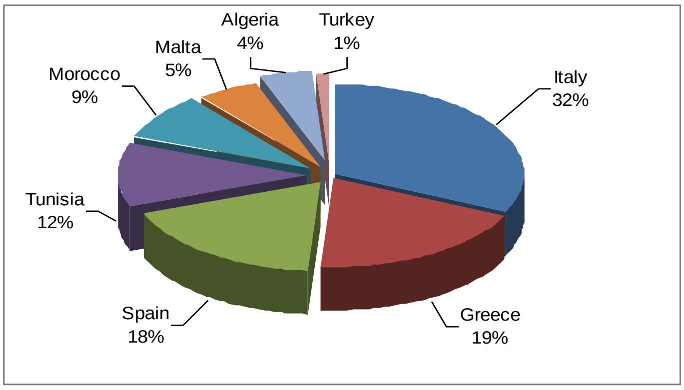

Figure 1. Percentage of Mediterranean countries in the total swordfish fisheries in 2013 (FAO, 2015).

***Tetrapturus belone* Rafinesque, 1810 Mediterranean spearfish**

The Mediterranean spearfish is a species of marlin native to the Mediterranean Sea where it is particularly common around southern Italy (Romeo *et al.,* 2009). This species is reported from the northern Aegean Sea (Akyol *et al*., 2013).

It is generally caught incidentally as a bycatch species in commercial long lines, driftnet and gillnet, and also in recreational fishing. Furthermore, according to Akyol *et al.* (2013), it is not rare for gillnets and longline fisheries in the northern Aegean Sea. In addition this epipelagic fish enters the shallow waters of İzmir Bay. The Mediterranean spearfish has minor commercial value in this basin.

***Coryphaena hippurus* Linnaeus, 1758 - Common dolphinfish**

Common dolphinfish is distributed widely in the tropical and subtropical waters of the eastern Atlantic, western Atlantic, western and eastern Indian Ocean (except possibly the Red Sea and the "Gulf"), western central Pacific, and throughout the Mediterranean, including the Aegean Sea and Marmara Sea (Ambrosi *et al*., 1994; Akyol *et al.,* 2012).

Common dolphinfish is a target species of commercial small-scale fisheries.This species is caught as by-catch in tuna and swordfish longlines, lampara, drifnet, purse seine vessels, and recreational fishing vessels (Palko *et al*., 1982). In the Mediterranean, this species is caught in association with fish attracting devices (FADS) and sport fisheries (Gatt *et al*., 2015). In the Aegean Sea, it is a by-catch species of the commercial long-line, drifnet and purse-seine fisheries of tuna species and swordfish (Akyol *et al.,* 2012).

***Scomberesox saurus* Walbaum, 1792 Atlantic saury**

Atlantic saury is distributed widely in the tropical and subtropical waters of Pacific, Indian, and Atlantic Oceans, and throughout the Mediterranean, including the Adriatic and Aegean Seas, to Morocco (Agüera and Brophy, 2011; Bilecenoğlu *et al*., 2014).

Atlantic saury is fast-growing and short-lived. Maximum size is about 26 cmFL. Spawning is believed to occur mainly during winter-spring, and the bulk of the spawning fish belong to age-groups 2 and 3 from the south of the frontal zone of the Gulf Stream (Dudnik *et al*., 1981). Very little information is available on its biology or population dynamics.

***Auxis rochei* Risso, 1810 Bullet tuna**

The bullet tuna is a cosmopolitan species inhabiting in the tropical and subtropical waters of world oceans. This fish is present in the Atlantic, Indian, and Pacific Oceans, including the Mediterranean Sea (Collette, 1986).

Minimum and maximum catch length of this species is reported as 28.5-44.5 cm and 34-48 cm from the Aegean Sea and eastern Mediterranean Sea (Bök and Oray, 2001; Kahraman *et al*., 2011). Life span is five years approximately, and males and females are of equal length (Collete, 2010). It is determined that the age range for this species is 0-4 and 1-5 for the Aegean Sea and the eastern Mediterranean Sea, respectively (Bök and Oray 2001; Kahraman *et al.,* 2011).

Bullet tuna are largely coastal spawners and spawning is thought to occur off Turkish water from May to September (Kahraman *et al*., 2010). Bullet tuna reproductive season extends from late August to mid September in the northern Aegean Sea (Vassilopoulou *et al*., 2008), The principal spawning grounds of bullet tuna have been found in the north Aegean Sea and in the coastal waters of central Greece (Koutrakis *et al*., 2004; Somarakis *et al*., 2011).

Bullet tuna is a very important commercial resource for various coastal and artisanal fisheries in the Aegean Sea.

The catch statistics are reflected together *Auxis rochei* and *Auxis thazard* by FAO database (Fig. 2 and 3). The total catch in 2013 was 863.3 t (Aegean Sea 481.4 t; Mediterranean Sea 351.9 t; and Marmara Sea 30 t) for Turkish waters (TURKSTAT, 2015). This fish has the lowest commercial values among the tuna-likes species.

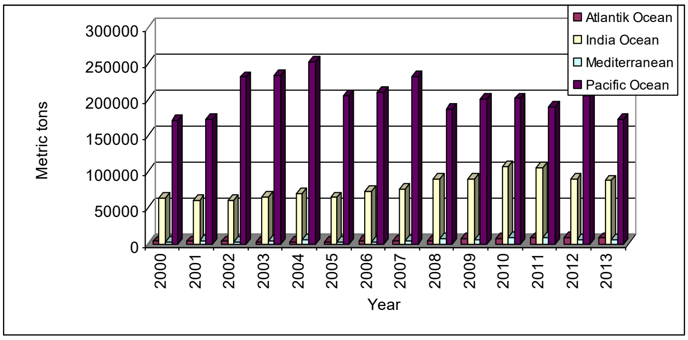

Figure 2. Total catch amount of frigate and bullet tuna in 2000-2013 by region (FAO, 2015).

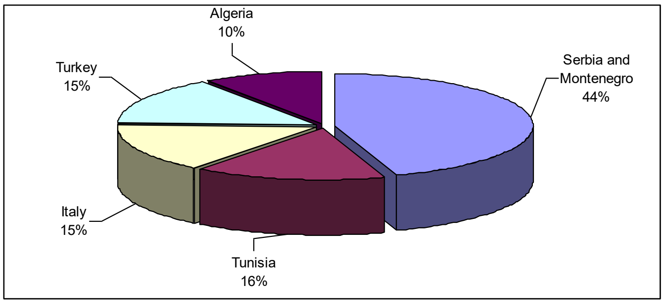

Figure 3. Percentage of Mediterranean countries in total frigate and bullet tuna catch in 2013 (FAO, 2015).

***Thunnus alalunga* Bonnaterre, 1788 Albacore**

Albacore is widely distributed in the major oceans of the world, including the Mediterranean Sea (Collette and Nauen, 1983). In the Mediterranean Sea the distribution of albacore is discontinuous with the highest concentrations occurring in the Tyrrhenian, Ionian, Adriatic and Aegean Sea (Megalofonou, 2000). There are six independent stocks of albacore worldwide, i.e. North and South Pacific, Indian, North and South Atlantic, and Mediterranean stocks (Nikolic and Bourjea, 2014**).** This species is commonly found in mixed schools with *Katsuwonus pelamis*, *Thunnus albacares* and *Thunnus maccoyii* (Collette and Nauen, 1983).

Maximum lifespan of albacore in the Atlantic is 13 years; while it is only 9 years in the Mediterranean. It is estimated that the age ranges from 1^+ to 9 years (57–92 cm FL) in the Aegean and Ionian Sea. The albacore reach sexual maturity at about three years of age (Megalofonou, 2000). The albacore reproductive season extends from June to September in the Aegean Sea (Vassilopoulou *et al.,* 2008), May to July in the eastern Mediterranean Sea (Akaylı *et al*., 2013).

The albacore is an important commercial tuna species, and a resource of high economic value for both large-scale industrial and small-scale artisanal fisheries (Saber *et al.,* 2015). It is caught mostly by longline, bait boat, trapnet, purse seine and trawl (Baez *et al*., 2011). Albacore fishing in the Turkish waters is performed using purse seines,long lines and gillnets in the Mediterranean and Aegean Seas.

The countries attributed with the highest catches of albacore are situated in the Mediterranean and Black Sea region (Figure 4). The largest landing area for this species in Turkey is the Aegean Sea with the amount of 57.8 t and it follows by the Mediterranean Sea with the amount of 12.8 t (TURKSTAT, 2015).

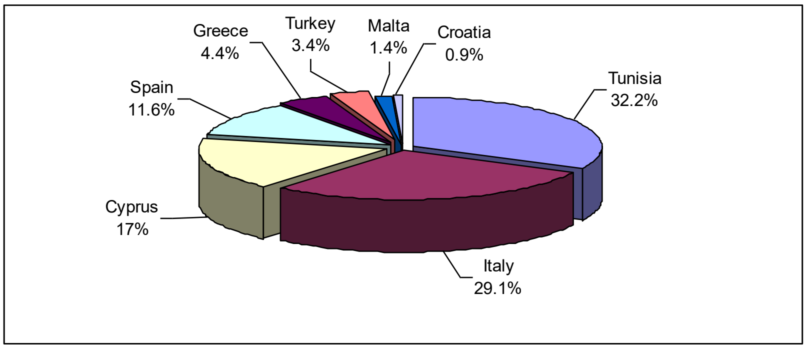

Figure 4. Percentage of Mediterranean countries in total albacore tuna fisheries in 2013 (FAO, 2015).

Euthynnus alletteratus **Rafinesque, 1810 Little tunny**

Little tunny is distributed in the tropical and subtropical areas. This species is the most common tuna in the Atlantic Ocean and including the Mediterranean Sea, Black Sea, Caribbean Sea and Gulf of Mexico (Valeiras and Abad, 2006).

This species is determined to be at age from 1 to 5 years (53.87–84.16 cm FL) in the Aegean Sea (Kahraman and Oray, 2001). The little tunny reaches sexual maturity at about 3 years of age. Fork length at first sexual maturity in males (42.8 cm) is smaller than in females (44.8 cm) (Hajjej *et al*., 2010). The Little tunny reproductive season extends from June to September in the Aegean Sea (Vassilopoulou *et al.,* 2008), and the spawning season of the little tunny in the Mediterranean is generally between May and September (Valerias and Abad, 2006) but the most intensive spawning occurs between July and August (Hajjej *et al*., 2010).

The minimum landing size of this species in Turkey is 45 cm and in other Mediterranean countries 30 cm (Albania and EC Italy), 40 cm (Algeria). The little tunny has been commercially exploited by seasonal artisanal fisheries in the Mediterranean Sea (Sabatés and Recasens, 2001). It is captured by using different fishing gears, such as purse seine, light fishing, gill nets, longlines, pelagic trawl, hand-line, beach seine, and trap (Hajjej *et al.,* 2013). Recreational fisheries also catching this species in the Turkish waters is performed using purse seines, set nets, and gillnets in the Mediterranean and Aegean Seas. The average annual catch (2000-2013) was estimated at 17,411.7 t. The largest landing areas are the Atlantic Ocean 13,281.4 t, Mediterranean and Black Area 4,130.2 t (FAO, 2015). Among these FAO areas, the Atlantic Ocean takes the first place with 75.5 %, followed by 24.5 % in the Mediterranean and Black Sea. The countries attributed with the highest catches of little tunny are situated in the Mediterranean and Black Sea region, asTurkey (1386 t), Egypt (849 t), Tunisia (800 t), Italy (557 t), and Spain (235 t) (Figure 5) (FAO, 2015). The largest landing areas for this species in Turkey are the Mediterranean Sea 1179.9 t, Aegean Sea 195.9 t, and Marmara Sea 10 t (TURKSTAT, 2015).

2. Conclusion

It can be concluded that the overview of the highly migratory fish species are related to intense commercial fishery. Although it is known regarding almost all these species, there is still lack of information about these highly migratory fish species in terms of biology, spawning area, time and migration especially in the Aegean Sea. There are also a lot of studies on demersal fish species in the Aegean Sea, except for the highly migratory fish species.

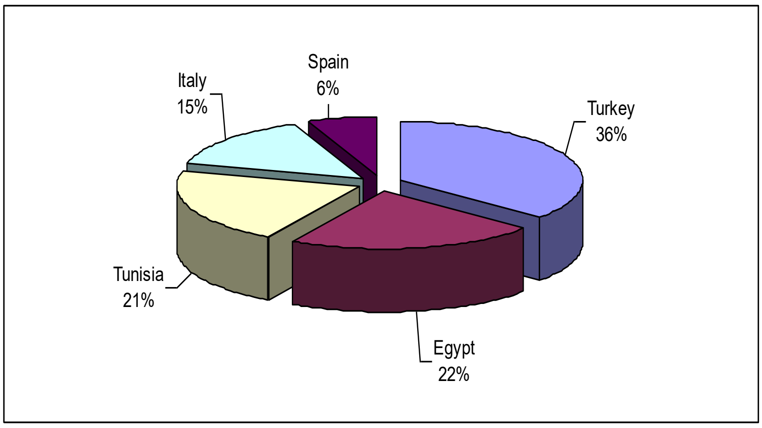

Figure 5. Percentage of Mediterranean countries in total little tunny fisheries in 2013 (FAO, 2015).

The species mentioned in this study have wide geographic distribution, both inshore and offshore, and they undertake migrations on significant but variable distances across oceans for feeding or reproduction. They are pelagic species with neritic and oceanic phases in their life cycle. We focused on the list that includes 4 tuna, 2 billfish and 1 dolphinfish species which are the most common highly migratory fish species in the Aegean Sea.

All these species are very important due to the volume of landings and their high economic value for the Mediterranean Basin. Among these species tuna-likes (*Thunnus alalunga, Euthynnus alletteratus*) and swordfish (*Xiphias gladius*) have high commercial value in the Aegean Sea. Apart form these species, other species like *Auxis rochei* has also significant importance in local fisheries. *Tetrapturus belone*, *Coryphaena hippurus* and *Scomberesox saurus* are not well documented in terms of quantity in the Aegean Sea according to EUROSTAT.

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DEEP WATER FISHERIES IN THE AEGEAN SEA

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1. Introduction

Commercial fishing has been started to operate in deeper waters globally. Increasing fishing pressure in coastal zones, conservative precautions and developing technological facilities are the main reasons of this case. By the effect of these reasons fishing fleets have been moving to deeper waters in order to make more efficient and profit catches. Morata *et al.* (2006) reported that marine fisheries worldwide have operated at increased depths since 1970s.

Deep-water fisheries may be defined as fisheries deeper than about 500 m, near the lower limits of the upper slope (Koslow *et al.,* 2000). Furthermore deepwater fisheries have been carried out between 250-450m depth in the Aegean Sea. While this type of fishery creates a positive trend for catch amounts, it becomes a matter of concern for scientists and environmentalists from the point of sustainability.

The European Union has adopted a number of regulations to manage deep-sea fisheries. The EU has been a party to the regulations negotiated by a number of regional fisheries management organizations (RFMOs) to manage deep-sea fisheries on the high seas. In addition, in 2008, the EU adopted a regulation designed to implement UNGA resolution 61/105 to prohibit bottom fishing in areas of the high seas not regulated by a Regional Fisheries Management Organization (RFMOs) without prior impact assessments and requires areas to be closed to bottom fishing where vulnerable marine ecosystems are known or likely to occur unless fishing can be managed to prevent significant adverse impacts on such ecosystems (Regulation (EC) No 734/2008). In this context, Deep-sea ecosystems were reported to be very vulnerable against the human based activities in this rudiment. For this reason, it was planned to obtain data and information from deep-sea fisheries in order to make arrangements for deep-sea fisheries. The goals of the arrangement are; sustainable fishing for the species of deep-sea fisheries, reducing by-catch, decreasing the vulnerability in deep-sea habitats and gaining more information on the biology of deep-sea species.

2. Deepwater fisheries of the Aegean Sea

Demersal trawling is the most important commercial deepwater fishing activity operating by the Turkish fisheries fleet in the Aegean Sea (Figure 1). Furthermore, gill nets targeting sole (*Solea vulgaris*) and trammel nets targeting common dentex (*Dentex dentex*) are used in the south part of the Aegean Sea between 80-100 depths. (Tokaç *et al.,* 2010). Recreational angling is another type of deepwater fisheries in the Aegean Sea.

3. Commercial Demersal Trawl Fishery

Although it is poorer in terms of nutrients compared to the Black Sea and the Sea of Marmara, the Aegean Sea is rich in the number of fish species (Tıraşın and Ünlüoğlu, 2012) The Aegean Sea has been showing the highest number of fish species as 449 taxa (Bilecenoğlu *et al.,* 2014). Marine living resources locating in the coastal waters of the Aegean Sea are under a high fishing pressure. Consequently, time and area restrictions are being applied in the mentioned area. It is forbidden to operate with trawlers and purse seiners from the 15th of April to 1st of September as a general law for Turkish seas. Within this banned period, weather permitting, the demersal trawl fleet tends to fish in relatively deeper, international waters of the Aegean Sea where the catch is usually higher (Tokaç *et al.,* 2010).

Figure 1. Catch composition of bottom trawl carried out in the deeper water of the Aegean Sea

Around some of the banks in the northern Aegean Sea such as Stok, Johnston, and Bruker are very important fishing grounds for bottom trawl fisheries. However, these banks are also ecologically significant in many ways and they have a large quantity of coralligenous assemblages and probably unique habitats in the Aegean Sea in terms of size and species richness (Öztürk *et al.,* 2009). These sensitive areas are also under the threat due to bottom trawling, purse seining, marine litter and marine transportation.

In the Aegean Sea, more than 50 species of fish, cephalopods and crustaceans are caught, almost exclusively by bottom trawls. Rose shrimp (*Parapenaeus longirostris*) and Norway lobster (*Nephrops norvegicus*) are the two main target crustaceans for the demersal trawl fleet in the international waters of the Aegean Sea (Tokaç *et al.,* 2009). Moreover, hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blennoides*), blackbelly rosefish (*Helicolenus dactylopterus dactylopterus*), fourspotted megrim (*Lepidorhombus boscii*) and Atlantic horse mackerel are main fish species that are caught by the bottom trawl in the deeper water of the Aegean Sea (Figure 2).

4. Conclusion

Deep-sea fisheries have become of the most important titles in the scientific community. Most importantly, it is because of the effect of deep-sea fisheries on benthic habitats (Koslow *et al.,* 2000). Secondly, deepsea ecosystems are generally located in international waters (Norse *et al.,* 2012) like in the Aegean Sea. Therefore, to achieve a sustainable fishery in the international deep waters brings many complex problems as well. The UNGA also requested that FAO develop ‘‘Guidelines for the management of deep-seas fisheries on the high seas.’’ (Norse *et al.,* 2012). These Guide-lines, adopted in August 2008, call for rigorous management of deep- sea fisheries throughout all stages of their development, and for keeping catch rates low until knowledge, management capacity and measures for monitoring, control and surveillance increase (FAO, 2009).

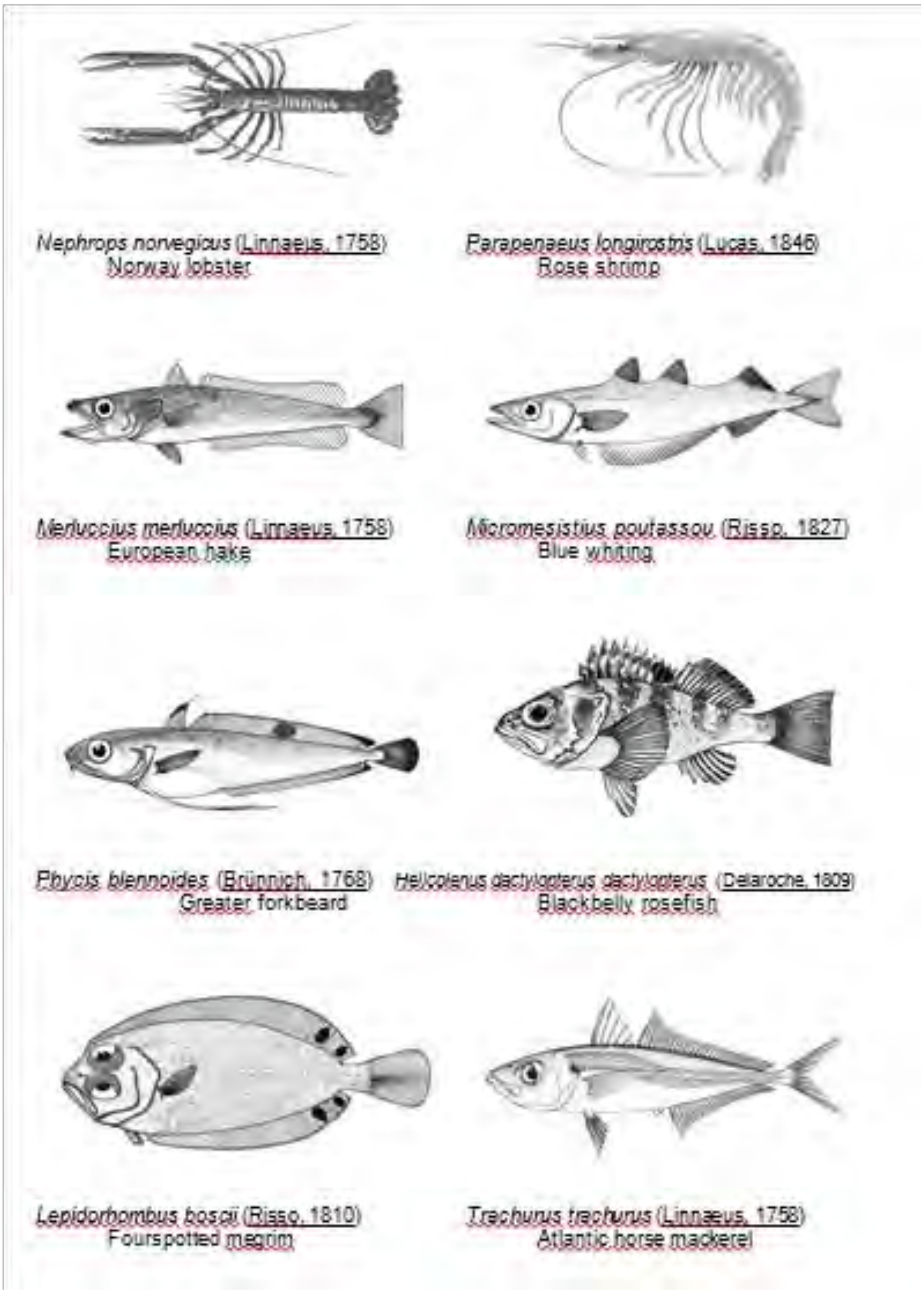

Figure 2. Main species which are caught by bottom trawl in the deeper water of Aegean Sea (Tokaç *et al.,* 2004).

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DISCARD AND BYCATCH OF THE AEGEAN SEA FISHERIES

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1. Introduction

Unwanted catch has become the one of the biggest problems in fisheries management. The sum of the global discards is 6.8 million tonnes for a total recorded landings of 78.4 million tonnes (Kelleher, 2005). Reasons of discarding are Phyisical and biological interactions, economic reasons, legitimate reasons (Alverson *et al.,* 1994). Among all fishing activities, demersal trawling generally has the highest discard ratios (Table 1.). Discard terminology and classification (Figure 1) is of crucial importance in order to make a certain evaluation and the most important one belongs to FAO Fisheries Report No. 547 (FAO, 1996):

Discards, or discarded catch is that portion of the total organic material of animal origin in the catch, which is thrown away, or dumped at sea for whatever reason. It does not include plant materials and post-harvest waste such as offal. The discards may be dead, or alive. Discarding is considered to be an act of volition requiring a decision by a fisherman to reject, or dump the fish. Discards do not include dead corals, or empty shells.

Bycatch: Bycatch is the total catch of non-target animals. Discards are not a subset of bycatch as the target species is often discarded.

Discard rate is the proportion (percentage) of the total catch that is discarded.

Catch: The term 'catch' is used to refer to the 'gross catch' Catch includes all living biological material retained, or captured by the fishing gear, including corals, jellyfish, tunicates, sponges and other non-commercial organisms, whether brought on board the vessel, or not. Plant material is not considered part of the catch for the purposes of this study.

Landings: The portion of the total catch brought ashore, or transshipped from the vessel. The 'landings' information contained in the discard database is derived from a range of different sources. For a given set of 'catch statistics' it may be difficult to determine whether the values are landed weights, or the live weight equivalent of the landings (= nominal catch as used in Fish stat).

Table 1. Summary of discards by major types of fishery (in tonnes) (Kelleher, 2005)

Fishery	Landings	Discards[1]	Weighted average discard rate	Range of discard rates
Shrimp trawl	1,126,267	1,865,064	62.3%	0%-96%
Demersal finfish trawl	16,050,978	1,704,107	9.6%	0.5%-83%
Tuna and HMS longline	1,403,591	560,481	28.5%	0%-40%
Midwater (pelagic) trawl	4,133,203	147,126	3.4%	0%-56%
Tuna purse seine	2,673,378	144,152	5.1%	0.4%-10%
Multigear and multispecies	6,023,146	85,436	1.4%	na
Mobile trap/ pot	240,551	72,472	23.2%	0%-61%
Dredge	165,660	65,373	28.3%	9%-60%
Small pelagics purse seine	3,882,885	48,852	1.2%	0%-27%
Demersal longline	581,560	47,257	7.5%	0.5%-57%
Gillnet (surface/ bottom/ trammel)[2]	3,350,299	29,004	0.5%	0%-66%
Handline	155,211	3,149	2.0%	0%-7%
Tuna pole and line	818,505	3,121	0.4%	0%-1%
Hand collection	1,134,432	1,671	0.1%	0%-1%
Squid jig	960,432	1,601	0.1%	0%-1%

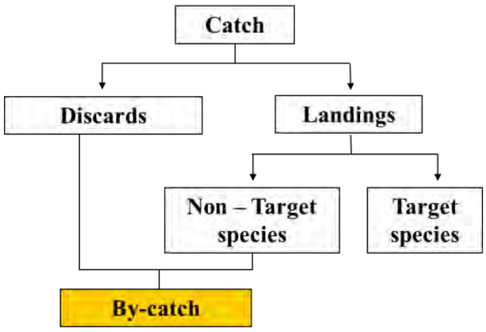

Figure 1. A general classification of the catch

2. Fishery by-catch & discards in the Aegean Sea

Aegean Sea which is a subunit of Mediterranean ecosystem is a crossroad of two continents, where different cultures co-exist. Economic and cultural characteristics regulate needs, demands, species prices and use of marine resources. Moreover multi-species/multi-gear nature of the fisheries highly varies catches, target species, sorting practices and by-catch/discards compositions among the different fishing gears. Some métiers catch a wide range of species; others can be extremely selective, with most of the catch dominated by one or a few species (Vassilopoulou, 2011). 10.2% of the Turkish fishery production has been gained from the Aegean Sea (TÜİK, 2013) and 80% of the production has been covered by the purse seine fishery (Kınacıgil and İlkyaz, 2012). Nevertheless data about the discarding character of fishing gears are scarce.

3. Overview of bottom trawl by-catch and discards in the Aegean Sea

The general absence of clear identification of the target species has led to the study of discards. Trawling is usually characterized by high discarding ratios which seem also true for the GFCM area. Kelleher (2005) reported a mean of 45% - 50% for trawl fishery in the Mediterranean with some exceptions (e.g. the Syrian trawl fishery) where discards are negligible. In many cases when target species are clearly defined, by-catch and discards present even higher ratios (e.g. shrimp trawl fishery). The range of discarding ratio highly fluctuates inter-annually, seasonally. Fishing depth, trawl duration and fishing intensity have also been shown to affect discards quantities in the GFCM area. Most studies report a high number of species that are always totally discarded, and a high number of by-catch species which are occasionally landed (Vassilopoulou, 2011). Soykan (2011) reported that the catch composition of Aegean Sea demersal trawl fishery was composed of 110 species, 9 of those were commercial, 72 were by-catch and 29 species took place in both commercial and by-catch having a discard ratio of 27.5%. Concerning the target species their discarded fractions are often negligible and comprise undersized or damaged specimens, but it is a fact that undersized individuals have also been marketed. Most common by-catch and discarded species in bottom trawl of the Aegean Sea are undersized or damaged specimens of commercial species such as *Merluccius merluccius, Parapenaeus longirostris, Aristeus antennatus Helicolenus dactylopterus, Pagellus bogaraveo* (Vassilopoulou, 2011;. Soykan, 2011). There are also species with low or no commercial value such as *Illex coindetii, Squilla mantis, Pagellus acarne, Boops boops, Spicara smaris, Diplodus annularis, Phycis blennoides, Galeus melastomus, Scyliorhinus canicula, Lepidotrigla cavillone, Centracanthus cirrus, Argentina sphyraena, Serranus hepatus, Lampanyctus crocodilus (*Vassilopoulou, 2011; Soykan, 2011).

4. Overview of purse seine by-catch in the Aegean Sea

Purse seines targeting small pelagic fish are generally characterized by low by-catch and discarding rates. Target species in Aegean and Mediterranean Sea purse seine fisheries usually represent more than 90% of the catch and most of the by-catch largely consists of commercialized species (Vassilopoulou, 2011). Discards on total catch ratio was negligible in many areas and was comparable to the weighted global average for purse seines (1.6%) (Vassilopoulou, 2011). Discard rates for mid-water trawls were higher but generally lower compared to bottom trawls. Tsagarakis *et al.* (2012) reported that the discarded quantities were on average 4.6% and 2.2% of the total catch in terms of weight in the Aegean and Ionian Seas respectively. Discards on the marketable ratio fluctuated over years and seasons without showing any particular trend. At the species level, sardine and mackerel were seldom discarded while large amounts of anchovy were discarded only during its recruitment period (autumn), when juvenile fish dominate the population. Nevertheless, lack of comprehensive scientific studies is a prevention for further discussions. Most common by-catch and discarded species for purse seine fisheries in the Aegean Sea are; *Trachurus mediterraneus, Engraulis encrasicolus, Sardina pilchardus, Sardinella aurita, Boops boops, Trachurus trachurus, Spicara smaris* (Vassilopoulou, 2011).

5. Overview of small scale fishery fleets by-catch in the GFCM area

Information on by-catch of the artisanal fishery is relatively scarce. Discards ratios are quite low (less than 10% on average for longlines, trammel and gill nets) and differ among métiers. The small-scale fishing fleet comprises numerous gears and exerts variable fishing practices targeting different species and resulting in different by-catch composition and quantities (Vassilopoulou, 2011). In certain cases discards are negligible, but by-catch can be relatively high since low commercial species are also utilized by the fishers for personal consumption or bait. Certain fisheries/métiers present higher discard rates (e.g. trammel nets for cuttlefish, shrimps and common spiny lobster). Low commercial value, damage at sea before retrieval of the gear and bad handling on-board are the main reasons for discarding. Gökçe and Metin (2007) identified 43 finfish and 29 invertebrate species from commercial prawn trammel net fishery in the Aegean Sea. They stated that 26 species landed by fishers and 46 species were discarded. Average ratio of landed to discarded fish by number and weight was estimated as 1 : 2.32 and 1 : 0.77, respectively, demonstrating relatively low by-catch ratios compared to other shrimp by-catch studies. Kınacıgil *et al* (2008) reported a discard ratio of 32% from bottom longlines in the Aegean Sea. Most common by-catch and discarded species in small scale fisheries in the Aegean Sea are *Scorpaena porcus, S. scrofa, Diplodus vulgaris, Diplodus annularis, Sardinella aurita, Serranus cabrilla, Symphodus* spp. for gill nets, *Synodus saurus, Boops boops Diplodus annularis, Sardinella aurita, Diplodus annularis, Pagellus acarne* for trammel nets, sharks, rays for bottom longlines and *Caretta caretta, Xiphius gladius* (by-catch), stingrays (*Pteroplatytrygon violacea*), pelagic elasmobranchs for pelagic longlines (Vassilopoulou, 2011).

6. Conclusions

In general, trawls are characterized by high by-catch and discards rates. Purse seiners and small scale fishery, even though they usually present lower by-catch rates, they may produce large discarded quantities since they are responsible for the bulk of landings in the Aegean Sea as a part of Mediterranean ecosystem (Vassilopoulou, 2011). Several studies describe promising technical improvements for by-catch mitigation that are or should be taken into account in fisheries management in the GFCM area. Effective technical measures may be gear - and fishery-specific and their application should be tested in different areas. Short and long term economic losses and gains should be explored and counterbalanced before decision making. However, the issue of selective fishing is not that simple since it can affect food-web structure and functioning, decreasing community evenness and species richness (Vassilopoulou, 2011). Learning to utilize a wider variety of products already comprised in the catch should be considered as an option of having a lower impact on the ecosystem. Under the framework of ecosystem based fisheries management clear objectives should be set for decision making on relevant issues. Disseminate successful technologies more widely and encourage their adoption. Comprehensively engage fishers themselves in finding appropriate solutions. Consider trade-offs from different approaches by interacting with key stakeholders, and select the best one, developing the appropriate institutional and legislative frameworks (Vassilopoulou, 2011).

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SPINY LOBSTER (*Palinurus elephas* FABRICIUS, 1787) AND COMMON LOBSTER (*Homarus gammarus* LINNAEUS, 1758) FISHING IN THE AEGEAN SEA

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1. Introduction

Spiny Lobster (*Palinurus elephas*, Fabricius, 1787) has a wide distribution in the East Atlantic, from Norway to Morocco, and in the Mediterranean Sea except in the eastern basin (Holthuis, 1991). However a recent checklist of marine arthropods of Turkish coasts reports it at Fethiye Bay, Eastern Mediterranean (Bakır *et al.* 2014). The lobsters prefers to live among rocks, in small caves with coralligenous beds at depths between 0 and 200 meters. Mature individuals are found as pair or in small groups. The lobsters are active at nights, but do not move except for feeding and reproductive activities. They are omnivorous, feeding on mollusca, echinordermata and crustaceas (Goni and Latrouite, 2005). *Palinurus elephas* has been assessed as vulnerable under criteria A2 (Goni, R., 2014).

Common lobster (*Homarus gammarus* Linnaeus, 1758) has a wide distribution in the world seas. They are found in the coasts of Britain, Sweden, Denmark as well as from Morocco to the north of Norway in the Atlantic Ocean. In the Mediterranean they are found in the coastal and island areas. They are also reported in the western Black Sea and Istanbul Strait (Bosphorus) (Holthius, 1991). Common lobsters generally prefer depths shallower than 150 m. This species uses rocky reefs for shelter, especially during moulting. They are active at night, feeding on mussels, crabs and polychaeta. They reach sexual maturity at 5 to 8 years depending on temperature. They are sedentary organisms and they migrate for 2-10 km to reproduce and feed (Prodöhl *et.al.,* 2006). *Homarus gammarus* has been assessed as Least Concern (Butler *et.al.,* 2013).

2. Lobster Fishing

P. elephas has been the target of fisheries off Ireland, England, Portugal, France, Spain, Tunusia, Morocco, Italy, Greece and also Turkey. Data on *P.elephas* fisheries are very scant despite their socio-economic importance. Traditionally, traps/pots or occasionally diving were used to capture *P. elephas***.** In the Mediterranean, this species is commercially exploited throughout its range where a decline of 30-50% over the last 30 years is estimated. Despite this decline in the Mediterranean, catch rates of

Spanish Mediterranean lobster fisheries (including both species) have remained stable for the last 10 years at levels about eight times lower than in a population protected in a MPA (Groeneveld *et al*., 2013).

The European lobster is mostly taken with lobster pots, although it occasionally turns up in trammel nets and dredges. Bait tied to lines can tempt them out of their burrows, after which they are caught by hand or with nets. In some areas captured specimens are kept alive in enclosures. This is an abundant species that is harvested in commercial quantities in parts of its range. The main fishing grounds are now the United Kingdom, Ireland, Channel Islands and France (Phillips B., 2013). Despite high commercial exploitation of this species for food, the global annual catch of this species has shown a steady increase over the last 30 years.

Lobsters were caught with baited traps until the 1960-1970s then an important change in the hunting strategy took place. Trammel nets replaced trap fishing. Although Mediterranean populations are thought to be overfished, they are still targeted in many areas, especially in remote areas such as archipelagos and islands.

In Turkey, boats registered to Cakıl village of Bandırma catch spiny lobsters and common lobsters in the northern Aegean Sea for two months every year (Öztürk, 2011). According to the Turkish fishery regulation circular (TFRC), it is forbidden to fish spiny lobsters and common lobsters except 15th April – 15th June in all of the Turkish territorial waters. However, they can fish out of the Turkish territorial waters by permission from Turkish Ministry of Food, Agriculture and Animal Husbandry. Besides, it is not allowed to catch spiny lobsters and common lobsters within the 1,5 miles territorial water in the north of Gökceada Island, between Kömür Cape and Kaskaval Cape; and within 3 miles in the south.

Although approximate two years ago these boats fished in the Northern Aegean sea including Saros Bay and Babakale (Gönülal, 2012), they catch spiny lobsters and common lobsters only among Gökçeada, Bozcada, Limni Island and 50-150 m depth in the northern Aegean Sea (Figure 1). Furthermore, two boats are reported fishing spiny lobsters in Foça (Central Aegean Sea) (Tokaç *et al.*, 2010). It is reported that spiny lobsters and common lobsters were caught by the nets for dentex (*Dentex dentex*) in Datca-Bozburun Semi Island (Southern Aegean Sea) (Akyol and Ceyhan, 2007). The lobster fishery in Turkey has traditions that can be traced back to the 1700's (Doğan, 2011).

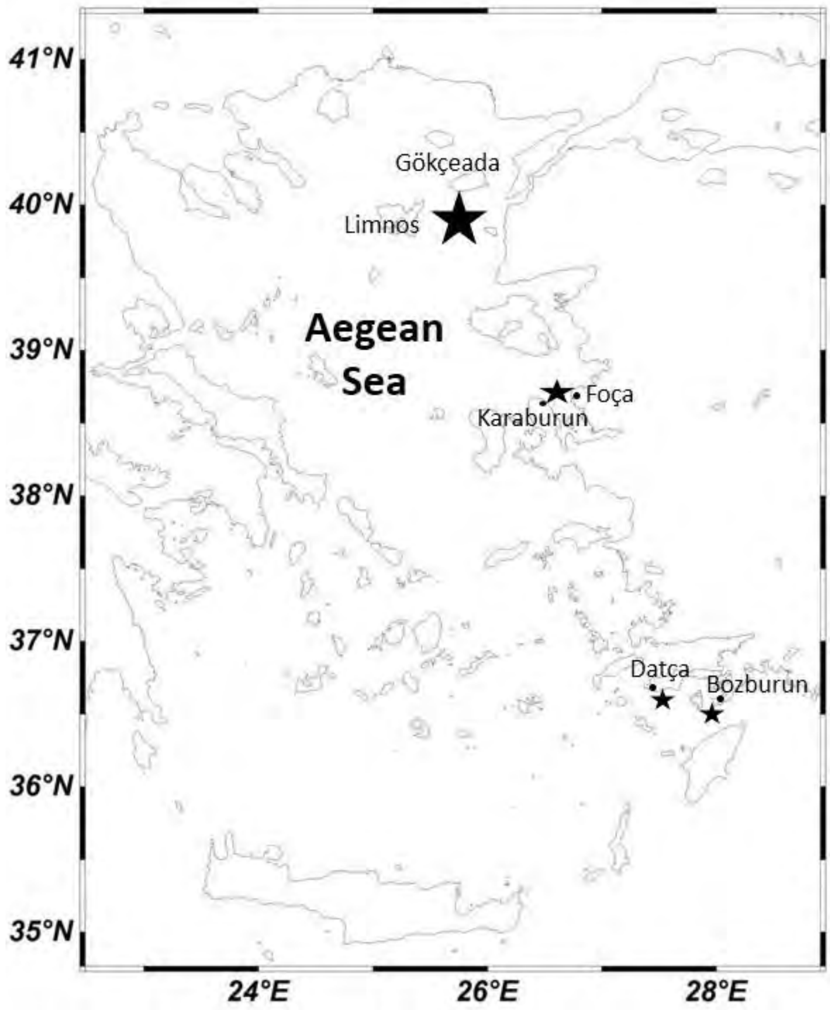

Figure 1. The main areas of lobster fishing in the Aegean Sea

Turkey's fishing fleet that catch the fish of the Aegean Sea is widespread stretching from the north to the south. Main fishing ground in the Aegean Sea off-shore area which are used by Turkish fishermen (Öztürk *et al.* 2002) (Figure 2)

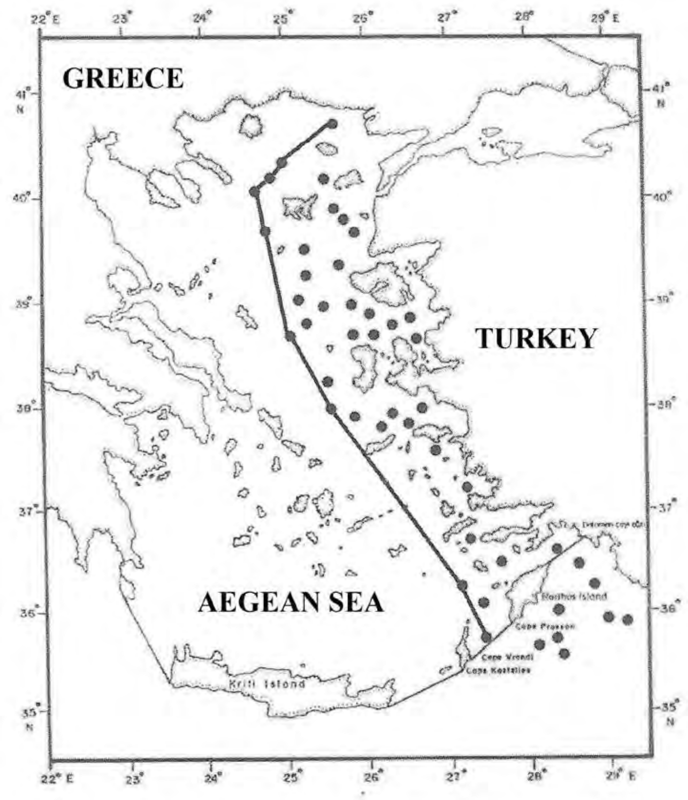

Figure 2: Main fishing off-shore area of the Turkish fishermen in the Aegean Sea (Öztürk *et al.* 2002)

Fishing boats set lobster-trammel nets in the evening and haul the following morning. Mesh size is between 85 mm and 170 mm, the depth for net is 9-12 m and the nets contain (PA) 210d/9. A float line consists of 157 floats (size 2), a leaded braid consists of 157 lead 50 g. The hanging ratio (E) is between 0.5 (float line) and 0.52 (leaded braid). A floatline is made of PP 4 mm, a lead line PP 3,5 mm twisted braid (Figure 3).

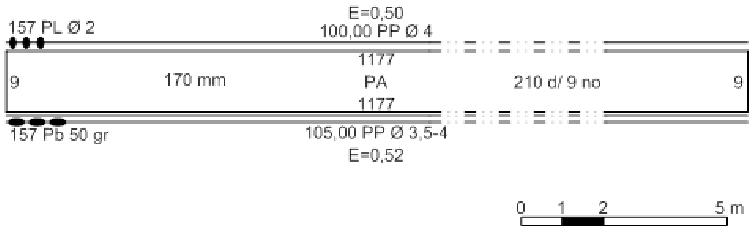

Figure 3. Lobster trammel net

Trammel nets are often rent and lost because they are used at the base of rocks and boulders. The major cause of gear loss is dragging on bottom structures. There are serious problems with losing their gears and recovering them from the reef areas where the fishery is intense. Lost trammel and gillnets are the cause of ghost fishing (Ayaz *et al.* 2010). Approximately, each fishing boat sets 6000 m of trammel nets in the area and haul every other day. The length and horse power of fishing boat are between 20 - 25 m and between 100 – 220 Hp respectively. Numbers of the fishing boat registered to the ministry are given in Table 1.

Table 1. Number of the fishing boat according to years (TUIK, 2014)

Year	2010	2011	2012	2013	2014	2015*
Number of fishing boat	12	10	8	6	3	2

*This data get information from “Gökçeada Directorate of Provincial Food Agriculture and livestock”

Lobster fisheries have so far been either unregulated, or only lightly regulated by national minimum legal size, supported in some countries by national or local prohibitions on landing egg-bearing females and/or closed seasons. From January 1st, 2002, EU minimum legal size of 87 mm CL (carapace length) came into force which is broadly equivalent to the mean size of first maturity but this varies from area to area throughout the range. In order to protect some endangered species, fishing is restricted during the appropriate period of reproduction of each species. The period between 1^{st} September and 31^{st} December, lobster fishing is not allowed. Additionally minimum size for some species including lobster, is also specified by a new EU Regulation 1967/2006. It is forbidden to fish or to trade in for lobsters that are below 420 gr weight. In terms of size, cathing common lobster with a total length below 300 mm TL or 105 mm CL; spiny lobster below 90 mm CL are also prohibited. According to Greek Legislation fishing is not allowed in terms of size below 240 mm TL for both lobster species (Kapantagakis, 2007). In Turkey, according to regulation 18.08.2012, 28388-2012/66 minimum legal size of lobster is 250 mm (total length). Until 2008, while minimum legal size is 200 mm for spiny lobster, it is 250 mm for common lobster. After that, minimum legal size was increased to 250 mm for spiny lobster. In addition, lobster fishing out of Turkish territorial waters which was limited to the region between Gökçeada and Bozcaada (northern Aegean sea) began to be allowed by Turkish Ministry of Food, Agriculture and Animal Husbandry as from 2013.

Catch, keeping on board, transhipping, landing, storing, selling and displaying or offering for sale of berried lobster are prohibited by REG. EC 1967/2006. Traps are used mainly for crustaceans and octopuses mainly along the north Aegean coast (Kapantagakis, 2007). The laws regulating the trap fishery are 1967/2006 which restricts the total number of traps per vessel to 250 for the fishing.

Because of the large mesh size opening, discard and non-target species are caught in small amount. However, fish, such as scorpionfish (*Scorpaena scrofa* Linnaeus, 1758), Black bellie dangler (*Lophius budegassa* Spinola, 1807), Blackhand sole (*Pegusa nasuta* Pallas 1814), are sometimes caught by the lobster nets.

On average five persons work on a boat and one of them is a cook. The total sale of spiny lobsters and common lobsters at the end of the season, after subtraction of the ship's stores and fuel cost, the 50 % of remaining amount and the rest of the amount are given to the boat owner and fishermen, respectively.

The fishermen remarks overfishing and that trawlers catch lobsters, but in the meantime trawlers catch fish illegally and this causes unfair competition. Some fisherman who used to catch 12 kg of lobsters years ago now can catch only 1-2 kg (Gönülal, 2012). Even prices in the best season do not exceed 25 € per kilogram. Table 2 shows the catches of spiny lobster and common lobster, between 2001 and 2015.

Table 2. Total quantity of caught lobster according to years in Turkey (ton) (TUIK, 2014)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	*2015
Spiny lobster	18	19	11	22	30	42	14,0	20	26	26	25,8	9,4	11,5	1,1	0,3
Common lobster	10	9	25	15	13	18	8	15,0	8	7	4,7	8	7	1,4	0,09

*This data get information from “Gökçeada Directorate of Provincial Food Agriculture and livestock”

3. Conclusion

The catch of lobsters in Turkey has been decreasing in recent years due to overfishing. The continuation of heavy fishing pressure will deplete the whole lobster stocks in the near future. Although Mediterranean populations are thought to be overfished, they are still targeted in many areas, especially in remote areas such as archipelagos and islands.

Our recommendations;

Boats greater than 50 gross tons shouldn't be licensed for lobster fishing. Boats licensed as purseseiners should fish only by purse seines, those licenced as trawlers should fish just by trawlers. In addition, these fishing boats must comply with the prohibition of place and time. Spiny lobster and common lobster fishing have been special artisanal fishing for years and it should be considered as sustainable fisheries.

Lobster boats fishing in the northern Aegean Sea have up to 10.000 m of trammel and nets are soaked 3 or more days. But there isn't any rule in Turkish legislations. Size and day limits should be regulated.

Traps represent one of the most selective gears and have the great vantage that specimens of species with no commercial value or undersized specimens can be released after the trap is recuperated. Even though berried lobster catch is prohibited by REG. EC, 1967/2006, some fishermen spoon berries from female lobster. Berried female lobster shall be returned at sea immediately after accidental catching. Traps also allow to be used for direct restocking of berried lobster. A study about fishing lobster using by trap in The Northern Aegean sea has been started by Gokceada Marine Research Department (Figure 4). Both traps and trammel nets generate bycatch, but while 66% of the individuals caught by traps are lobsters, in trammel net catches this proportion declines to 43% (Goni *et al.* 2003). In additions, Alverson and Hughes (1996)'s more comprehensive study point out that in traps lobster still made up 61% of the catch (in number) while in trammel nets lobster made up only 1.4% of the catch (in number). The ecological efficiency of the trap fishery reached 97% while that of the trammel net fishery reached only 1.8%.

Finally, marine reserves appear to be the only new method envisaged so far for the recovery of lobster stocks and apart from a total ban, fishing with above mentioned methods could be allowed whereas the use of trammel nets should be completely prohibited. Protected lobster populations are expected to contribute to the replenishment of fished populations through increased egg production. In the Mediterranean populations of lobster, egg laying takes place from August to October; the egg carrying period from October to March and hatching from December to March but mainly in January and February (Diaz, 2001). Correlates between settlement and water temperatures might suggest a role for temperature in the settlement success. The settlement took place in june-july, after sea surface temperature started to rise. The highest density of juvenile was found at 10-15 m depth. Most lobsters settled in limestone rocks, into empty holes of mussels (*Lithophaga lithophaga, Pinna nobilis* etc), which provided daytime refuge. As they grew, individuals were increasingly found in larger holes and crevices of the rock surface. Deveciyan (2006) mentioned, about 1.500 spiny lobster and 30.000 common lobster arrive at İstanbul fish market per year in 1900s. Now, this amount has clearly decreased (see Table 2). So, we suggested a marine reserve among Gökçeada, Bozcaada and Lemnos Island considering suitable habitat types for lobster settlement.

Here, major problems in the management and exploitation of lobster fisheries are summarized in relation to the increased fishing effort associated with technological advances in hauling gear. We should focus on developing performance indices, both ecological and economic, of the fisheries to provide operative advice for the sustainability of lobster fisheries.

Figure 4. Experimental traps used for lobster fishing at Gökçeada (Northern Aegean Sea)

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FISH AGGREGATION DEVICES (FADs) APPLICATIONS ALONG THE AEGEAN COAST OF TURKEY

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1. Introduction

Any type of structure deployed on the water surface or just below the surface in order to attract pelagic fish species is called Fish Aggregation Devices (FADs) or Floating Artificial Reefs (FARs) (Bergstrom, 1983).

Fish Aggregation Devices (FADs) were first used in the Mediterranean. Romans used FADs made from fungus tree in fishing *Coryphaena hippurus* and *Naucrates ductor* around 200 A.C. (Bombace, 1989; Morales-Nin *et al.,* 2000). Besides the Mediterranean, similar FAD designs were observed in Japan in the 1600s (Kakuma, 2000) and in Pacific countries such as Indonesia, Malaysia and the Philippines in the 1900s (Boy and Smith, 1984). An industrial aspect since the 1970s FADs have been used in fishing species like *Scomber japonicus*, Seriola spp., *Coryphaena hippurus* and Thunnus spp. both in the coastal region and in oceans (Marcille, 1979; Friedlander *et al*., 1994). The first FAD program was implemented in Hawaii in 1977 and this was followed by programs in other Pacific countries, particularly in Japan (Matsumoto *et al.,* 1981; Holland *et al.,* 2000).

In the Mediterranean Sea, FADs are used in the Middle and Western parts (Relini *et al.,* 1994; Andaloro *et al.,* 2007). The traditional type FADs made from plant materials are called *Kannizzati* and pelagic fish species such as *Seriola dumerili*, *C. hippurus*, *N. ductor* ve *Thunnus sp*. are caught especially in summer and autumn (D'Anna *et al.,* 1999; Deudero *et al.,* 1999; Massuti *et al.,* 1999; Potoschi *et al.,* 1999).

Today, it is known that FADs are used in more than 30 countries in various designs. Use of FADs is quite common in the purse seine fishing carried out particularly in the Pacific and Indian Oceans. Using hundreds of thousands of FADs, more than 250000 tons of tuna are caught every year (Fonteneau *et al.,* 2013; Davis *et al.,* 2014).

2. What is FADs?

Fish aggregating devices (FADs) are anchored or drifting objects (both natural and man-made) that are intentionally put in the ocean to aggregate fish. Pelagic fish such as marlin, tuna and dolphin fish are attracted to FADs for various reasons, including shelter, thigmotropism (the attraction to a solid object), the presence of small prey, the smell and sound of the FAD structure. FADs also act as a breeding area and attract the schooling of certain species (Gooding and Magnusan, 1967; Dempster and Taquet 2005). Worldwide, more than 300 species belonging to 96 families of fishes have been observed in association with floating structures (Castro *et al.,* 2002).

FADs, are used extensively for recreational (Holland *et al.,* 2000), small-scale (Morales -Nin *et al.,* 2000) and large scale commercial fisheries (Fonteneau *et al.,* 2000). Fishing on floating objects has existed for a long time, but the practice of using artificial FADs really took off in the 1990s and has become more and more important. FADs have been considered one of the significant developments in recent years for enhancing recreational and commercial fisheries, especially in industrial tuna fisheries (Caddy and Majkowski, 1996). This is highly advantageous to fishing as floating objects aggregate sparsely distributed schools, are more easily spotted than tuna swimming freely beneath the surface, stabilize schools and reduce the speed at which they travel, making them comparatively easy to catch (Fonteneau *et al.,* 2000).

FADs built from various materials in order to aggregate schools of pelagic fish are composed of 3 sections

a) The Buoy: This is the section of the device which floats on the water. It enables the whole system to float. It is made of various materials ranging from trees to steel or fiberglass buoys. This section of the device may contain solar-powered lights and radar reflectors for sea transportation security reasons. The parts of the buoy remaining under the sea serve as a sheltering area for the fish (Gates *et al.,* 1998; Holland *et al.,* 2000).

b) Attractor: This is the section which remains under the water and is used to attract fish. Any type of materials from old fishnet parts to palm tree branches or metal of plastic plates can be used as the attractor. Fish are attracted to this section due to its movements in the water as well as providing a shelter, harboring and feeding area for them (Gates *et al.,* 1998; Dempster and Taquet, 2004).

c) Mooring System: This is the section which connects FADs to the sea bottom and is composed of ropes, chains, connection equipment and the anchor. Depending on the size and location of the FAD, different anchoring systems can be used varying from natural fibers to chain and synthetic ropes. Today, FADs which are planned by calculating the strengths of waves, currents and winds can easily be anchored as deep as 2000m (Gates *et al.,* 1998).

Based on their use, FADs are grouped into 3 as anchored to the sea bottom (a), mid-water (b) and drifting (c) (Figure 1).

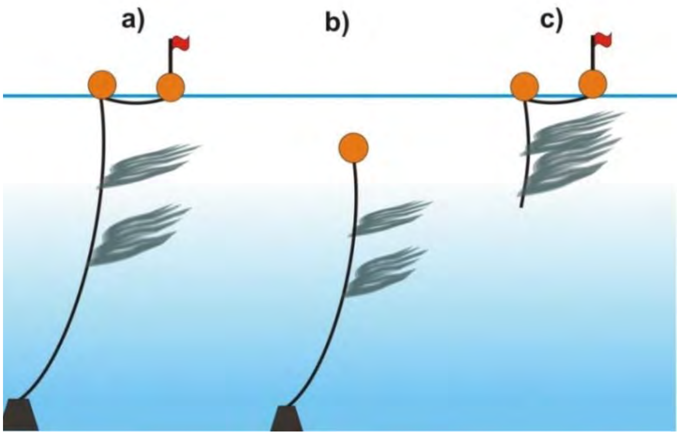

Figure 1. Anchored (a), Midwater (b) and Drifting (c) FADs Tipleri (Özgül, 2010)

While the buoy section is on the sea surface in FADs anchored to the sea bottom, this section remains under the water in mid-water FADs. In drifting FADs, on the other hand, there is no mooring system. Therefore, radio or GPS transmitters are used to detect the location of FADs. They particularly of this type are found in tuna fishing activities in the Pacific and Indian Oceans (Fonteneau *et al.,* 2013; Davis *et al.,* 2014).

FADs are divided into two as traditional and modern depending on the material they are made from and their designs (Hillborn and Medley 1989).

Traditional FADs: In their buoy and attractor sections, traditionally plant materials such as bamboo or palm tree are preferred as well as others like old fish net parts, barrels, car tires etc. FADs of this type are low cost and mostly placed in coastal waters. Their life cycles range between 3 months and 1 year (Boy and Smith, 1984; Preston *et al.,* 1998).
Modern FADs: They have longer service lives and are used in deeper waters in comparison to traditional FADs. Instead of natural materials, steel, aluminum, polyethylene or fiberglass materials are used in their buoy sections. In the mooring system, sinking-floating ropes, chains and various connection elements are used. Having radar reflectors, GPS transmitters and solar-powered lighting systems, these designs also serve as a meteorology station with the meteorological measurement devices they have on themselves particularly in Japan. The cost of these systems is higher than that of traditional systems. Activities of placing them are rather undertaken by governments or National fisheries cooperatives (Anderson and Gates, 1996; Chapman *et al.,* 2005).

Figure 2. Traditional (left) and Modern (right) FADs (Mars, 2007; Moloney, 2007)

3. FADs Applications in the Aegean Sea

While no evidence is available for the use of FADs, which have long been used in the world seas and the Mediterranean, by fishermen in the Aegean Sea, there are some scientific studies (Akyol *et al.,* 1997; Vassilopoulou and Anastasopoulou 2007; Altınağaç *et al.,* 2010; Özgül, 2010). These studies aimed to determine the fish community structure around FADs and to evaluate the possibilities to use FADs in the pelagic fisheries sector (Figure 3).

Greek Waters: The first applications of FADs in the Greek waters of the Aegean Sea were carried out by the Hellenic Centre for Marine Research (HCMR). FADs associated fish communities in waters of the south Peloponnisos (between May 2000 and April 2001) and around Dodekanisos- Kalymnos Island (August-November 2003 and July-November 2005) were studied to gather data on spatial and temporal colonization of FADs in the Hellenic seas. Traditional FADs were constructed by tying 4-5 palm leaves together and mooring them in depths from 40 to 250 meters. A total of 13 species, six of which belonged to the Carangidae family, were recorded around FADs in Greek waters. In particular, in Peloponnisos waters*, C. hippurus* was one of the most important species of the FAD community in terms of percentage relative abundance (number of individuals per FAD), followed by *N. ductor*. In the Dodekanisos *C. hippurus* exhibited significantly lower abundance and *N. ductor* was absent from n the FAD vicinity, while small juveniles of *Caranx crysos, Balistes carolinensis* and *S. dumerili* dominated (Vassilopoulou and Anastasopoulou 2007).

Turkish Waters: The first study in the Aegean Sea was carried out in the Gulf of İzmir. 3 FADs were placed at 10 depth 200 m off the shore equipped with palm leaves, fish net parts and red canvas as the attractor. Visual counting technique, trammel net, trap and angling were used as the sampling method. Among the FAD designs, the one made of fish nets was found to be the most successful design. A total of 26 fish species were detected in the study and the most frequently recorded species around the FADs were *Diplodus annularis, Trachurus trachurus, Labrus* sp. (Akyol *et al.,* 1997). It was noticeable that 78.6% of the species detected consisted of demersal fish species.

Another study conducted in the Turkish territorial waters of the Aegean Sea was held in Çeşme-Gerence Bay. In this study, the FADs were placed at 25-35 m depth 3 km off the shore. While 3 different designs were employed in the study, ropes, nylon and polyester were used as the attractor. The sampling method of the study was visual counting, trammel nets and angling and 16 fish species belonging to 11 families were detected. It was highlighted that the use of FADs in the region increased the number of species in the environment and that FAD designs made of ropes were more efficient than the others (Altınağaç *et al.,* 2010). *Trachurus* spp and *Boops boobs* species were found intensively in the study.

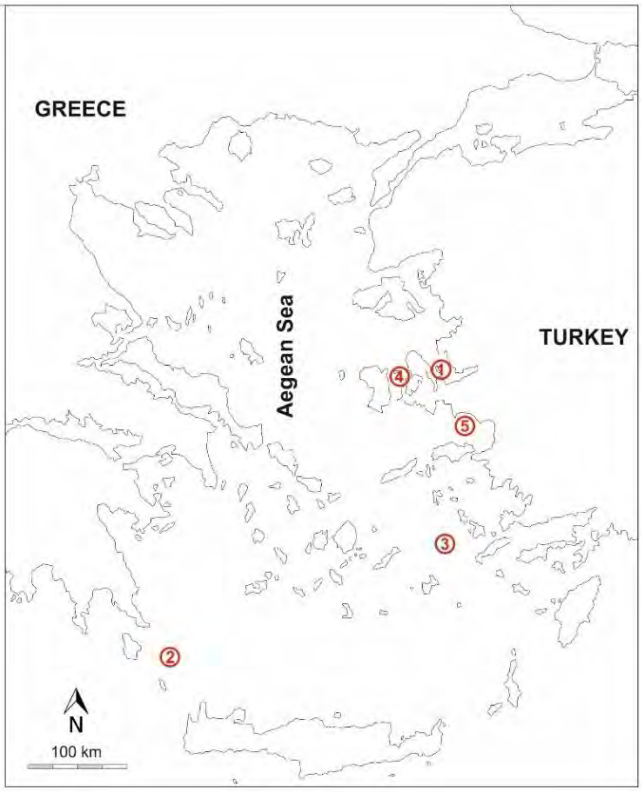

Figure 3. FAD applications in the Aegean Sea. 1. İzmir Bay (Akyol *et al.,* 1997); 2. Southern of Peloponnisos; 3. Dodekanisos-Kalymnos Island (Vassilopoulou and Anastasopoulou 2007); 4. Çeşme-Gerence Bay (Altınağaç *et al.,* 2010), 5. Gulf of Kuşadası (Özgül, 2010)

In these studies conducted both in the Turkish and Greek territorial waters of the Aegean Region, FADs of traditional style were placed in the coastal waters. On the other hand, a TUBITAK-supported study carried out by Ege University Faculty of Fisheries in the Gulf of Kuşadası in the Aegean Sea used modern FAD designs which are suitable for long-term use. In this study, which aimed at increasing fishing of pelagic species in the Aegean Sea, FAD models of modern style that are used in Pacific countries were redesigned by considering the waves and currents in the Aegean Sea.

3.1 FAD Design and Deployment

Two FADs (steel spar buoys) were constructed and moored in depths of 50 and 100 m deep of water Gulf of Kuşadası in the Aegean Sea to support pelagic fisheries. FADs were deployed at a distance of 1.1 to 3.0 nautical miles offshore respectively (Figure 3).

FADs have three separate float-tanks to prevent sinking. All the components of the FADs were made of steel protected by anti-corrosive paint. In addition, they were equipped with flashlight for avoiding sea accidents. Pad-eyes were fitted to the upper and lower parts of the buoys for the mooring of fishing vessels and as attractors. As well as the aspects of the engineering design, the shape of FAD units was also designed to attract surface migratory fish by changing the pattern of the current around the floating reef body (Figure 4).

FADs were connected to an anchor by a combination of chain, sinking and floating ropes and other components (shackle, swivel, rope connector etc.). The anchor, which was made of reinforced concrete, weighed approximately 2.76 metric tons. When performing the FAD and mooring system design, wave, current and wind effects were evaluated using the stability equation before deploying the FADs. The interaction between the forces of wave and current and FADs in those waters was investigated. In the experiment, all forces (drag force, buoyancy force etc.) acting on FADs were calculated (Özgül *et al.,* 2011). FAD units were moored there in 2008 to assist the R/V EGESUF (26.8 m length, ~500 HP engine). In the placing operation, by using the crane on the ship, first the floating section and then the anchoring system were launched while the ship was proceeding slowly and finally the system was fixed at the desired coordinates by releasing the anchor (Figure 5).

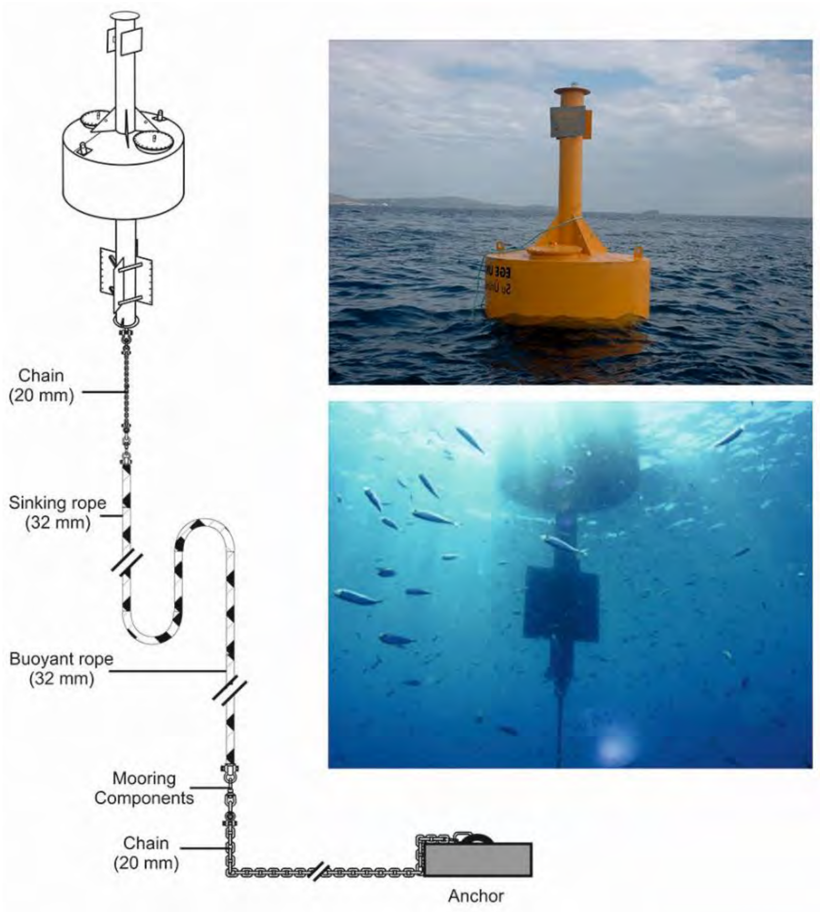

Figure 4. Design of FADs and Mooring System (Özgül, 2010).

Figure 5. Deployment of FADs in the Aegean Sea (Özgül, 2010)

3.2 Fish Community Structure and Fisheries around FADs

The fish fauna associated with FADs in the Aegean Sea were similar to earlier findings reported for Mediterranean waters. Although in the Mediterranean Sea, D'Anna *et al*. (1999) 8 fish species; Andaloro *et al.* (2007) 10 fish species; Relini *et al.* (2000) 12 species; Castro *et al.* (1999) 15 species were reported. In the Aegean Sea, Akyol *et al.* (1997) 26 species, Vassilopoulou and Anastasopoulou (2007) 13 species, Altınağaç *et al.* (2010) 16 species were reported.

30 species belonging to 21 families around of FADs was reported by Özgül (2010). By far the most frequently observed families were Sparidae, Carangidae and also Scombridae. *Trachurus mediterranus, S. dumerili,* and *C. hippurus*, were the species most abundant observed beneath FADs (Table 1).

Table 1. Fish abundances associated with FADs in the Aegean Sea coast of Turkey

Species	**FAD50**	**Length (cm)**	**FAD100**	**Length (cm)**	**Total**
Euthynnus alletteratus	1	60.0	-	-	1
Scomber scombrus	4	6.0-30.2	-	-	4
Scomber japonicus	16	17.2-31.8	-	-	16
Sarda sarda	-	-	1	32.6	1
Engraulis encrasicolus	6	7.0-9.5	7	9.1-22.1	13
Sardina pilchardus	551	8.0-14.0	-	-	551
Belone belone	-	18.0	1	90.5	1
Trachurus trachurus	4	13.2-22.0	-	-	4
Trachurus mediterranus	2485	5.0-26.8	230	5.0-12.0	2715
Seriola dumerili	104	8.0-23.3	541	3.0-33.4	645
Naucrates ductor	20	4.0-8.0	1	8.0	21
Pseudocaranx dentex	36	12.0-18.0	-	-	36
Xiphias gladius	5	73.0-115.0	6	62.0-113.0	11
Coryphaena hippurus	65	30.0-120.0	405	32.0-107.0	470
Lepidopus caudatus	7	78.5-110.0	1	82.5	8
Balistes capriscus	9	10.0-12.0	56	10.0-27.0	65
Boops boops	274	7.0-28.2	-	-	274
Pagellus bogaraveo	77	8.6-14.2	-	-	77
Pagellus erythrinus	44	10.1-23.2	-	-	44
Pagellus acarne	28	11.0-16.5	-	-	28
Diplodus annularis	8	7.6-16.1	-	-	8
Diplodus vulgaris	4	8.6-9.4	-	-	4
Serranus scriba	2	10.6-15.7	-	-	2
Lophius piscatorius	1	24.4	-	-	1
Centrolopus niger	-	-	1	30.0	1
Zeus faber	-	-	1	22.0	1
Merlangius merlangus	-	-	1	23.5	1
Raja polystigma	1	54.5	-	-	1
Myliobatis aquila	1	54.0	-	-	1
Illex coindetti	1	32.5	2	37.5-41.4	3
Total	3754		1254		5008

Table 2. Experimental fisheries (H. Long line, angling, gill-net and trolling) results from FADs and control stations (weights, g in brackets)

Species	**FAD50**				**FAD100**				***Total***
	P. Longline	*Trolling*	*Angling*	*P.Gillnet*	*P. Longline*	*Trolling*	*Angling*	*P.Gillnet*	
E.alletteratus		1 (176.0)							1 (1760.0)
S. scombrus	1 (107.2)			3 (9.6)					4 (116.8)
S. japonicus	1 (235.5)		14 (1458.7)	1 (272.3)					16 (1966.5)
S.sarda								1 (736.7)	1 (736.7)
E.encrasicolus				6 (63.9)				7 (73.8)	13 (137.7)
B.belone								1 (883.5)	1 (883.5)
T.trachurus			4 (209.5)						4 (209.5)
T.mediterranus			11 (1225.1)						11 (1225.1)
S.dumerili			6 (637.2)			2 (309.5)	27 (4230.3)		35 (5177.0)
X.gladius	5 (28845.0)				5 (31520.0)	1 (2077.0)	2 (1787.4)		13 (64229.4)
C.hippurus	1 (5498.0)	13 (16532.1)			5 (13239.7)	12 (17462.1)			31 (52731.9)
L.caudatus	3 (1583.0)				1 (360.1)				4 (1943.1)
B.capriscus							3 (967.4)		3 (967.4)
B.boops			248 (10038.1)						248 (10038.1)
P.bogaraveo			77 (1422.2)						77 (1422.2)
P.erythrinus			44 (1686.6)						44 (1686.6)
P.acarne			28 (663.0)						28 (663,0)
D.annularis			8 (456.2)						8 (456,2)
D.vulgaris			4 (216.0)						4 (216,0)
S.scriba			2 (60.3)						2 (60.3)
L.piscatorius				1 (165.9)					1 (165.9)
M.merlangus					1 (115.4)				1 (115.4)
R.polystigma	1 (1302.2)	4 (2149.7)							5 (3451.9)
M.aquila	1 (1220.0)								1 (1220.0)
I.coindetti				1 (68.3)				2 (180.7)	3 (249.1)
Total	13 (38790.9)	18 (20441.8)	447 (18096.9)	12 (580.0)	12 (45235.2)	15 (19848.6)	32 (6985.1)	11 (1874.8)	560 (151853.3)

Data were analyzed by station as well as according to experimental fishing methods. *S. dumerili, C. hippurus,* and *X. gladius* on the other hand, were more abundant at the *FAD100* which moored at 100 m isobath and at a distance of 3 nautical miles from the coast. This species were caught from especially FAD100 with pelagic long lines and trolling. Especially, *X. gladius* was recorded around FADs for the first time in Aegean Sea waters; this species has economic value for commercial fisheries. Notwithstanding trolling was an important fishing method for game or sports fisheries. Pelagic longlines were more productivity method for commercial fisheries methods for FADs fisheries.

4. Conclusion

FADs, which are used for scientific purposes only in the Aegean Sea, have been used in both traditional and industrial aspects in the Mediterranean for years. Scientific studies have shown that FADs can be used in fishing for pelagic species also in the Aegean Sea.

In Turkey, purse seine fisheries have the biggest role in fishing for pelagic species. In purse seine fishing, discovering fish schools is the most important step of the fishing operations and the biggest cost is on fuel expenses. Although FADs are used in the fishing of pelagic fish primarily tuna in the world, no record is available on the use of FADs in Turkey. Especially, in the tuna fisheries that have recently accelerated in the Eastern Mediterranean and Aegean Sea in order to provide tuna aquaculture facilities with fish, using drifting FADs may be helpful in reducing fuel costs.

FADs can use as a tool for supporting to small scale and recreational fisheries. In addition to purse seine fishing, by using FADs in the pelagic longline fishing practiced with traditional methods in the continental shelf fishing can be done for species such as *X. gladius*, *C. hippurus* and *S. dumerili*. Moreover, with trolling to be used in fishing for these species, recreational and sportive fishing can be supported in the coastal area.

The number of net-cage fish farms has increased rapidly in the Aegean Sea over the last 20 years. In these facilities where fish with high economic values like sea bream, sea bass and tuna are cultivated marine aquaculture facilities serve as FADs. Sea-cage fish farms attract wild fish by providing structure in the pelagic environment, and uneaten feed and feces that fall through the cages may enhance the attractive effect (Özgül and Angel 2013). The fish community structure around these facilities must be examined and organized both in the field of fisheries and ecology.

A legal regulation is available on artificial reefs which are deployment sea bottom in Turkey. However, this regulation does not include FADs. Thus, a regulation must be developed on the issue by the ministry, university and fishermen's cooperatives coming together and the number of FADs to be used and the distance between FADs must be examined in detail in this regulation. Indeed, the number of FADs in shallower waters should be managed because FADs can play a negative role in the population of fisheries in coastal waters.

Acknowledgements

I would like to thank Altan Lök for his advice, assistance, and insight regarding my research their critical review of my studies.

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LAGOONS FISHERIES IN THE TURKISH PART OF THE AEGEAN SEA

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1. Introduction

Lagoons are defined as aquatic environments that are separated from the adjacent seas by natural or artificial sets formed from sands and/or other sediments and connected to the sea with straits in different numbers and dimensions that facilitate the exchange of salt water from the sea, thus, having different salinity values changing from brackish water to hypersaline water (Ardizzone *et al.,* 1988).

Lagoon regions are very important for fauna and flora and during the investigations on these areas, it should be considered together with natural life, residential areas, the supply of water resources and the sea at its coast (Hekimoğlu, 2001; Emiroğlu at al., 2002; Elbek at al., 2003). As result of different factors, the alterations or deteriorations in the structures of these constituents might damage the natural balance. In this context, the importance of the lagoons that are considered as very special aquatic areas has been increasing rapidly. It is not a sufficient measure to leave these regions to their fate by taking the lagoons under protection for the continuity of sustainability. Precautions should be taken against the important threats like pollution, shoaling, depletion of fresh water resources, eutrophication and hypersalinity.

In Turkey, containing coastal structures suitable for lagoon formation, there are 72 lagoons and it known that 40% of these lagoons are located at Aegean Region. However, fish production is not performed *et al.* lagoons. Total surface area of the lagoons in Turkey are 38.000 ha, in which, the proportion of the lagoons at Aegean Region are 54%. Also, 63% of the fishery productions achieved from all lagoons are obtained from these lagoons. In this context, the lagoons of Karina, Güllük, Akköy and Homa, accepted as important ones in the Aegean Sea, were investigated including their assessment in terms of general characteristics, social structure, production status, legal status and sustainability were discussed.

2. Lagoons of the Aegean Sea

In this paper, the lagoons that are actively working in the Aegean Sea were considered. The lagoon of Enez which is currently active and having a coast near the Aegean Sea and found within Marmara Region was not taken into consideration.

2.1. Güllük Lagoon

The Güllük lagoon was investigated under five subheadings including general characteristics, social structure, production status, legal status and sustainability.

2.1.1. General Characteristics

The Güllük lagoon (37°15' N, 27°38' E) is located at the south of the Aegean Sea and east of the Güllük Bay (Figure 1). The lagoon is 40 km far away from Bodrum and it is possible to reach from Güllük to lagoon area within 15 min. The lagoon is located in 250 ha of a wide marsh area and 800 acres of lake area. The Güllük lagoon is surrounded by the lands of national treasury, foundations, forests and individuals. There are many lands of marsh and unused lands that are not suitable for agriculture. Limni Lake, from the lakes that forms the lagoon region, Limni and Karakemer lakes, is fed with General Directorate of State Hydraulic Works drainage canal and a weak water resource that is close to dryness almost along the year. The materials coming from the drainage canal increasingly causes the shoaling of the lagoon. The fresh water supply of the lagoon is achieved from Sarıçay stream and the canal constructed by General Directorate of State Hydraulic Works. However, this water is not suitable for the lagoon since it is used in washing of tobacco and cotton fields (Erdem, 2006).

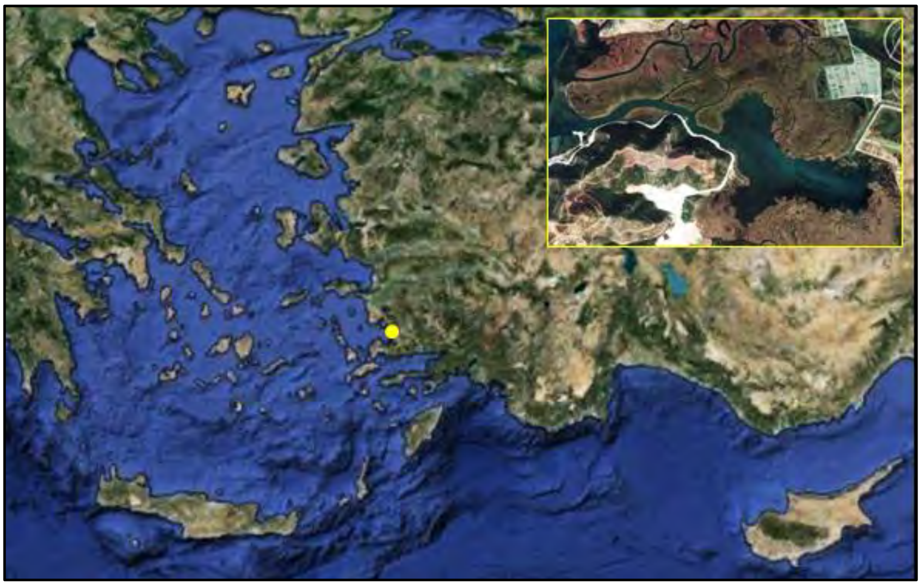

Figure 1. The location of Güllük Lagoon at Turkey and Aegean Sea.

Sarıçay Stream, carries the water of Yaykin Lake, feeds the canals connecting the lagoon area to the sea. Precipitation area of the Sarıçay reaches 152 km^2 at Akgedik region and 664 km^2 at the exit of Karagöl regulator. Sarıçay enters to the Karagöl following the Milas plain at east-west direction. Later, it reaches to the Tekfurambarı plain by leaving a canal of the regulator. At that location, it connects with the Acıçay that is coming from the fronts of Sepetçiler and Savran villages and drains to the Güllük lagoon. In addition, Hamzabey streams grows at the height of 1200-1350 m, passes the Alaçam plain and then runs from a very narrow and deep valley and reaches to the Tekfur plain. Due to the risk of flood and formation of a marsh in that plain, Hamzabey stream was distorted from its bed. It was transported and controlled near Limni Lake by passing along the plain's south end within a walled bed. Both Sarıçay and Hamzabey stream have some important branches. Between these branches, Derince stream, originates from the slopes of Yaylacık Mountain at north-western part of the basin, flows along the Söke-Milas highway and enters the Selimiye plain, crosses that plain at south-east direction and reaches to the Karagöl near Asinyaniköy. Also, Gökçay and Bokluçay fresh water streams are connected to the lagoon area (Önen *et al.,* 1998; Egemen *et al.,* 1999).

The minimum and maximum depths at the lagoon area were 1.12 m and 2.40 m, respectively. It was reported in the area calculation with planimeter that the deepest point was 150 cm with an area of 1.214 km^2 and the area at 70-80 cm of mean depth was 668.176 km^2. It was found that mean temperature and salinity values within a year were 19.53±3.48 °C and 10.65±0.881‰, respectively. The annual mean of dissolved oxygen was found as 7.32±0.692 mg/l. The mean pH was measured as 8.006±0.088. The amount of yearly seston was determined as 8.22±1.682 mg/l. Since the entrance of the lagoon is under the influence of continuous water inflow and outflow, this leads to the increasing levels of seston (Egemen *et al.,* 1999; Emiroğlu *et al.,* 2002).

At the measurements of nutrients in the lagoon area, ammonium levels were high (4.39-29.70 µg-at l^{-1}), nitrate (0.81-17.87 µg-at l^{-1}), nitrite (0.19-1.35 µg-at l^{-1}), phosphate (0.01-0.45 µg-at l^{-1}), and silica (0.26-6.00 µg-at l^{-1}) were found at lower levels. Annual mean of chlorophyll-a was determined as 5.51±3.409 µg/lt. Güllük lagoon is under the influence of domestic and agricultural pollution coming from the Güllük and adjacent regions. The cause of organic pollution increasing at the winter is its transportation via precipitation. In addition, total coliform, fecal coliform and fecal streptococci was found as >24x10^3, 24x10^2 and 18x10^3, respectively (Egemen *et al.,* 1999; Öztürk *et al.,* 2006).

The phytoplankton species distributed in the lagoon were determined as *Cyanophyceae, Bacillariophyceae, Dinophyceae, Chlorophyceae, Zygophyceae* and *Desmidiaceae*. In addition, pennant diatom species such as *Navicula* sp., *Melosira moniliformis, Surirella fastuosa, Cocconeis* sp., *Ceratoneis* sp. were also observed. Benthic organisms belong to Nemertina, Polychaeta, Oligochaeta, Crustacea, Mollusca, Insecta, and Echinodermata groups were observed.

Besides its economic value in terms of fishery products, Güllük lagoon is also one of the important nesting places for birds. Spur-winged plover (*Vanellus spinosus*), black-winged stilt (*Himantopus himantopus*), Izmir kingfisher (*Halcyon smyrnesis*), pied kingfisher (*Ceryle rud*is), green bee-eater (*Merops orientalis*) and penduline tit (*Remiz pendulinus*) are some of the birds brooding at that region (Ertan *et al.,* 1989).

2.1.2. Social Structure

Güllük is located at the coast of Güllük Bay (also known as Mandalya Bay) Güllük Harbor, found at the same region, is a very active place since it is a shipping point for feldspar reserves at the area. Besides the harbor, fishing and tourism are the most important economic activities for the area (URL 1).

2.1.3. Production Status

In the lagoon, barrier traps, trammel nets and fyke nets are used for production. Barrier traps are closed at the period of June-January and kept open at the rest of the year. The lagoon area was rent to the members of S.S. Güllük Fisheries Cooperative and Kıyıkışlacık Fisheries Cooperative on 2012. The production, previously made with 167 motorized fishing boats changing between 6-9.5 m, is just performed with special wooden boat “kuruta” now (Erdem, 2006; Tokaç, 2010). The productivity of the lagoon is decreased compared to the previous years. Previously, mostly the mullet species (*Liza aurata, Mugil cephalus, Liza saliens Mugil capito, Chelon labrosus*), sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*), common sole (*Solea vulgaris*), white sea bream (*Diplodus sargus*), striped sea bream (*Lithognathus mormyrus*), bluefish (*Pomatomus saltatrix*), horse meckerel (*Trachurus trachurus*), Atlantic bonito (*Sarda sarda*), European eel (*Anguilla anguilla*) and common carp (*Cyprinus carpio*) were being caught in the lagoon (Elbek *et al.,* 2003), however, now only mullet, sea bass, gilthead sea bream, European eel and much lesser common sole is being caught. At the beginning of 2000’s yearly fish production was reported as 54 tones, but, on 2014, it was reported about 30 tons of which 14 tones were obtained from barrier traps and 15 tones from the lagoon. Besides, yearly 200 kg of caviar is being produced from fish catchments. Also, the juvenile sea breams that were caught from the lagoon were taken for feeding to the sea cages in the lagoon (100.000 fishes in 1998, 68.000 in 1999). This application was cancelled after the banning of the catchment of juvenile fishes from the nature. There are 2 straits at the construction area of barrier traps found in the connection area of Güllük lagoon to the sea. The widths of the barriers found at north are 52 m and 75 m for the south. The mean depths of the straits changes between 2.5-3.0 m. There are 2 independent canals are connected at the entrance of the lagoon. The entrance of the canal found at the north and close to the sea is very shallow. There are barrier traps made of metallic material with a traditional style at the second southward entrance. There are 4 barrier traps at both straits made of wire materials (Figure 2) (Elbek *et al.,* 2003; Erdem, 2006).

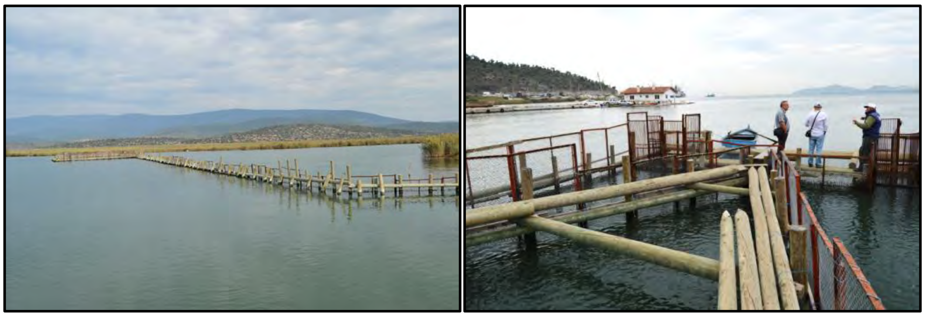

Figure 2. The trap system and barrier traps at the Güllük Lagoon

2.1.4. Legal Status

Güllük Lagoon, being the source of income for the fishers at Güllük, was rented to the cooperatives found at the region until 2007. Since the continuous reports of cooperative stating the loss of income and detection of illegal juvenile ponds at the lagoon, rental was cancelled on 2007 by special provincial administration due to the lagoon's non-formal management. Legal problems were continued until 2012 and problems ended after the going out to the tender for the lagoon. After the tender, management rights of the lagoon were given to the S.S. Güllük Fisheries Cooperative and Kıyıkışlacık Fisheries Cooperative.

2.1.5. Sustainability

The most important reason for the decreasing of lagoon's production about by half in the last 10 years is the increasing shoaling at the lagoon area. At the same time, the natural structure of the lagoon and its management process was not conserved and, in addition, big constructions like harbor and airport were made. The feldspar mine opened at the area and use of the harbor at the transfer of the mine causes precipitation of the inorganic material at the lagoon region.

Güllük Lagoon is the main reserve for the water accumulated at the area. Güllük Lagoon was formed at the drainage point of the Sarıçay where the rain and underground water pooled together. There are high mountains at the north and south of the lagoon. The east part of the lagoon is opened to the sea and its west side is a plain. Milas plain is formed from lands available for agriculture. In the past, the floods formed especially at spring were transferred to the sea via Güllük Lagoon. Later, Sarıçay and main canal system was connected to the sea by the canal systems constructed against the floods by

General Directorate of State Hydraulic Works. However, this protection mechanism prevents the transfer of the materials by floods from the lagoon to the sea. As a result, the shoaling has increasingly continued at the lagoon area especially within the last 20 years. Therefore, shoaling has become one of the most important problems of the lagoon (Figure 3). Sarıçay is needed to be directed towards the lagoon at specific months of the year and main strait of the lagoon should be deepened for prevention of the problem and the controlling the rate of shoaling. By the help of these efforts, the sustainability of the production in the lagoon could be established.

Figure 3. Güllük Harbor, the accumulation of feldspar at the lagoon area and shoaling.

2.2. Karina Lagoon

The Karina lagoon was investigated under five subheadings including general characteristics, social structure, production status, legal status and sustainability.

2.2.1. General Characteristics

Dilek Peninsula that contains the Karina lagoon area is found within the city of Aydın and placed at the edge of Dilek Mountain extending to the Aegean Sea. It is about 20 km long and its mean width is 6 km. Sisam Island is found at the counterpart of the national park and Dilek Peninsula part of the national park is found at the last section of Samsun Mountains extending to the Aegean Sea. Dilek Peninsula was declared as a national park at 1966. Büyük Menderes Delta was participated to the national park at 1994. The total area of the national park is 27.598 ha, the peninsula is 10.895 ha and delta is 16.613 ha. Maquis flora is dominant at the peninsula and Black Sea flora is also distributed at the north slopes. Delta region is an important habitat for migrant birds and at the same time spawning area for marine fishes.

Büyük Menderes Delta has the property of internationally important "Class A Wetland". It is also important for containing the elements of the flora from Mediterranean, Europe and Siberia regions. Due to its richness Dilek Peninsula and Big

Menderes Delta is accepted by European Commission as "Floral Biogenetic Reserve Area". At the same time, Büyük Menderes Delta is a part of an integrated wetland with the Bafa Lake. This integrated system has international importance for containing biological diversity, endangered and endemic species and it is under international protection by Ramsar Convention, Bern Convention, Rio Convention and Barcelona Convention.

The flora of the region is represented by 804 taxon at the level of species, subspecies and varieties belong to 95 families. There are 163 Mediterranean elements, 159 East Mediterranean elements, 33 Europe-Siberia elements, 12 Iran-Turan elements and 30 endemic species between the taxon. In spite of the peninsula is placed at Mediterranean flora region, it also hosts Europe-Siberia species. It is the only place for Anatolian chestnut endemic to North Anatolian forests and also for snowball (*Viburnum opulus*), Phoenicean juniper (*Juniperus phoenicea*), evergreen oak (*Quercus ilex*) and Mediterranean cypress (*Cupressus sempervirens*) found as little communities. At north, red pine (*Pinus brutia*), black pine (*Pinus nigra*), Phoenicean juniper (*Juniperus phoenicea*), Mediterranean cypress (*Cupressus sempervirens*), oak (*Quercus* sp.), chestnut (*Castanea sativa*), maple (*Acer negundo*), lime tree (*Tilia tomentosa*), ash tree (*Fraxinus excelsior*), at valleys, plane tree (*Platanus orientalis*), at south, carob tree (*Ceratonia siliqua*), heather (*Erica manipuliflora*), myrtle (*Myrtus communis*), eastern strawberry tree (*Arbutus andrachne*), sweet bay (*Laurus nobilis*), turpentine tree (*Pistacia terebinthus*), strawberry tree (*Arbutus unedo*), redbud (*Cercis siliquastrum*) and broom (*Spartium junceum*) is found. In addition, the salinity of the surrounding area of the lagoon is high, therefore, the flora is weak and there are halophilic plants at some regions (URL 2).

The coasts of Dilek Peninsula are also a natural habitat for Mediterranean seals that are the rarest mammalian species of Europe. In addition, many animal species including wild boar (*Sus scrofa*), caracal (*Caracal caracal*), jackal (***Canis aureus***), hyena (*Hyaena hyaena*), domestic cattle (*Bos primigenius taurus*) and horses (*Equidae* sp.) are found at the peninsula. Delta hosts 28 mammalian and 27 reptile species of which 24 of them are endemic (6 of them at worldwide, 16 of them nationwide). It is determined that 256 bird species were distributed at the region, 68 of them nests at the delta and surrounding places. Also, it hosts numerous birds and it is a nesting area for Dalmatian pelican and pygmy cormorant that are endangered species (URL 2; URL 3).

Karina Lagoon is the biggest lagoon in the Büyük Menderes Delta and also it is one of the most important lagoons of the Aegean Region and found at 37° 37' to 37° 33' north, 27° 08' to 27° 13' east coordinates. The lagoon is separated from the sea by a waterfront and it has a connection at the north. Its connection at south is lost with time (Figure 4).

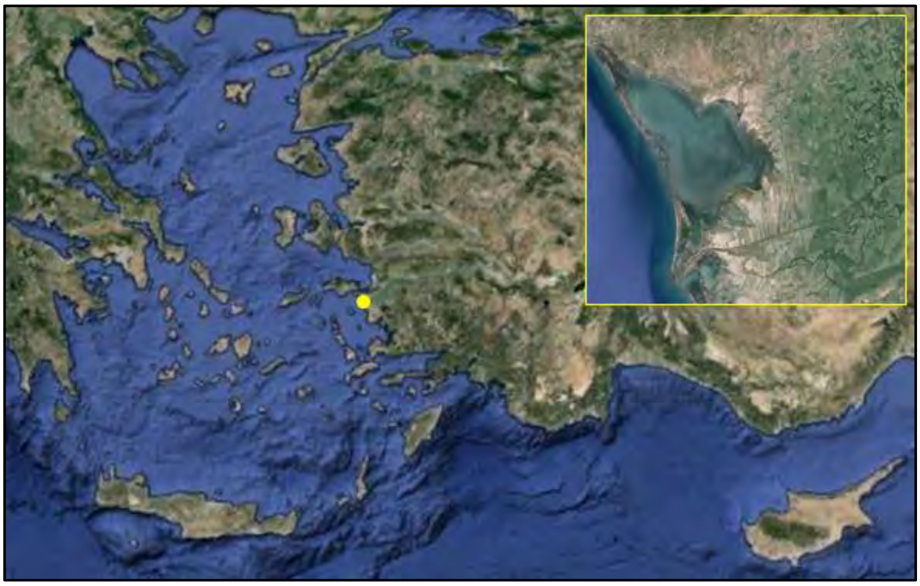

Figure 4. The location of Karina Lagoon in Turkey and Aegean Sea.

From administrative point, the lagoon is found within Söke county of Aydın city. It is 38 km far away to county center and 89 km to Aydın city. At the same time, Dilek peninsula is found at the Büyük Menderes part of the national park and has the form of triangle. Its area is about 2460 ha. Temperate climate conditions are dominant at the region and the deepest part of the lagoon is 170 cm and has the status of wetland with high productivity.

2.2.2. Social Structure

The lagoon area hosts Doğanbey and Tuzburgazı villages. The income for 150 of these is coming from the fishery or both fishery and agriculture.

The income for 5-6 of these is coming from the fishery or both fishery and agriculture. The population that works on fishery is denser at Doğanbey. There are 800 people living at the both villages.

2.2.3. Production Status

Karina Lagoon is a high productivity wetland that juveniles of valuable species such as sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*) and mullet (*Mugil* sp.) are crossed intensely to lagoon in the Aegean Sea but recently production rate has been dramatically decreasing compared to the past. The highest production amount was reported as 107 tons in 1994. However, regional fishery has nearly collapsed due to disruption on water balance of the lagoon area, intense fishing and pollution. In 1990, 1169 members of about 10 cooperatives in this region captured more than 600 tons; however, this amount was decreased to 100 tons in 1995. Likewise, fishermen of lagoon reported that "in the past, fishing was about 500-700 kilos, but nowadays this amount is decreased to 150-200 kilos per day." It is reported that annual productivity of Karina Lagoon is 80 tones. Production in lagoon is provided from fishing and there are no controlled production conditions and/or wintering channels (deep water sheds).

There are 4 main channels that are called Karina, Tek Dam, Pale, and Arita Channels. Except these channels, there are 2 admitted channels; one of them is called Soğan Channel where next by Karina and Yeni Channel. Soğan Channel is in action radius of Karina Channel and thus it is not accepted as differently. Also, opened channels have been closed. Two of four main channels -Pale and Arita Channels- which have separately water input and output were closed and their barrier traps have been removed. Today, inputs and output of sea water has been flowed by Karina and Tek Dam Channels. The longest channel is located on the north edge of the lagoon and both channels have been separated by bamboo materials and wooden vaults (Figure 5). There are several brackish water springs on the south and southeast of the lagoon. In the past, freshwater flows were high amount but nowadays this is dramatically reduced. Average thickness ranged between 15-20 mm bamboo materials were used in shutter parts and barrier traps of Karina Channel; contrast to metallic materials in the modern systems. Bamboos are usually tied sequentially by string and/or herbal fiber and the distance of two bamboos is ranged 5 to 15mm.

Figure 5. Barrier trap systems in Karina Lagoon

2.2.4. Legal Status

The lagoon is located in the Dilek Peninsula National Park and under responsibility of Regulations on Wetlands' Protection of Ministry of Environment and Urbanization, Law of National Park, Ramsar Convention, Bern Convention, Barcelona Convention, and Rio Convention. Therefore, this case caused to some limitations on actions in the lagoon area.

Ramsar Convention is aimed to declare that wetlands have a great source in terms of economical, scientific and recreational ways and also to warn that there is no turn back in case of losing of wetlands, and mainly to stop all operations potentially destroy wetlands. Karina Lagoon area is one of them.

Bern Convention is recorded that many species belonging to wild flora and fauna are seriously endangered and also it is crucially important to protect of their habitats. According to Bern Convention, some regulations are closely related with the Karina Lagoon. Also, it is estimated that national policies about protection of the habitats of endangered and potentially endangered species by the partner countries of this convention should be determined.

As part of Barcelona Convention and Special Protected Area and Biological Diversity Protocol, Turkey is responsible for establishment of special protected area for special, natural and cultural areas and also to sustain, protect environmental friendly and manage of them. Karina Lagoon is a special protected area and under protection by this convention and related protocols.

According to Regulations on Wetlands' Protection of Ministry of Environment and Urbanization, prevent of pollution in wetlands, incorruption of natural infrastructures and ecological characters are protected and also prevention of functions and value of wetlands should be guaranteed during the planning of using of water sources and terrain. Any rehabilitation works and development projects on this land should be depend on permissions from related ministries together with Ministry of Forestry. Besides, these studies are controlled according to rules of the Law of National Parks. Recent production operations are carried out according to reference to article 13 of the related law.

2.2.5. Sustainability

During the past three decades, Karina Lagoon was lost its degree from multiple water input lagoon to limited water input lagoon class and also it is probably that it will be reduced single water input class due to closing of Karina Channel and finally Karina Lagoon will be permanently closed in the near future due to reducing of the freshwater from channels of Büyük Menderes River, over vaporization and consumption of water by living organisms (Özden *et al.,* 2014). Therefore, it is obvious that main problem of Karina Lagoon is shoaling. Alluvial deposit from the Büyük Menderes River and erosion of Dilek Peninsula, are the main factor on this shoaling. Opening of the drainage channels which are built for prevention of overflow especially winter and spring is obstructed the discharge of loads out of the lagoon area. Obtained data from the bathymetric study conducted 10 years interval revealed that elevations below and above the water level are point sources not plenary and also accelerative effects of spaces between these elevations on shoaling will be continued increasingly. Continuing of bathymetrical movements on two open channels, obligation of moving of barrier traps are clearly verified of shoaling in channels and risk of closing of the lagoon.

It is clearly estimated that Karina Channel will be closed permanently due to effect of both erosion and shielding of the Dilek Peninsula and also no counter force to prevent reducing of these effects (Figure 6). Tek Dam Channel, the another open one, is exposed on stronger northwester and southwester wind, and also forced by lagoon and Büyük Menderes due to closing of Pale and Arita Channels. Despite these effects, shoaling is being continued but it is spread plenary and speed of shoaling is getting slower, due to these two strong forces. However, the system is started to build a set about 250 m average distance from the inside of lagoon area to channels. Moreover, it is predicted that this set will establish a support point and also it will accelerate the closing process of the channel from inside to outside entirely (Figure 6).

Figure 6. Annual variations of shoaling on channels of Karina Lagoon

In order to avoid the existing shoaling problems in the Karina Lagoon, a connection has been built by channels from three barrier traps to deep zone of lagoon center. Closing of Arita Channel which is located in the far south is caused to decrease of lagoon cycle but not permanently stop due to entering of some water sources from this region. In case of closing of Karina Channel, there is no point of water input to support lagoon cycle and also decreasing of water quality parameters at the north side is expected. It is quite important that providing the freshwater effects on the south side will increase productivity in lagoon. Therefore, there is a necessity to design a water budget program about more active usage for Büyük Menderes River in order to use it effectively. This case is highly important for sustainability of Karina Lagoon which is one of the largest and vital lagoons in Turkey.

2.3. Akköy Lagoon

Akköy Lagoon was investigated under five subheadings including general characteristics, social structure, production status, legal status and sustainability.

2.3.1. General Properties

Lagoon area is located 37°29' North-27°12' East coordinates (Figure 7). There is also a little area called Tuz Lake between Karacagöl and Arapça lagoon. Lagoon area covers 1.700 hectares area. In the past, although former bed of Büyük Menderes River was located between Arapça Lake-Karacagöl and Bölme-Kabahayıt lagoon area, river bed was changed due to water support for agricultural activity, and moved to area where is located Karina and Akköy Lagoon. There are no freshwater inputs on lagoon area except precipitation and deep water springs.

Figure 7. Location of Akköy Lagoon in Turkey and in the Aegean Sea

Dilek Peninsula has been declared as National Park in 1966. Also, Büyük Menderes Delta was added the National Park area in 1994. As shown in Figure 8, Karina and Akköy Lagoon are separated by Büyük Menderes River but they are located in the same geographic region. Besides, fauna and flora characteristics of Akköy Lagoon are in similar with the Karina due to located in the same region. This part has been defined in detail at the general characteristics of Karina Lagoon.

Figure 8. National Park Borders in the Region

2.3.2. Social Structure

Akköy is a village where located in the western Turkey. Population of Akköy where lagoon is located is about 1500 people. Fishing is one of the main sources of income, whereas 70% of people provide their lives by fishing.

2.3.3. Production Status

Akköy Lagoon area is consisted of 4 lagoons named as Arapça, Karacagöl, Bölme, and Kabahayıt Lagoons (Figure 9). It is well known that the production rate was highly notable in the past. The production amount was about 200 tons in 1990's but nowadays it has been decreased to 80 tons due to changing of river bed and shoaling of connection channels between lagoon area and the sea. Besides, illegal and overfishing by seine vessels in front of the lagoon area are caused to decrease in fish amounts.

Figure 9. Water areas formed Akköy Lagoon

In lagoon, mullets (*Mugil* sp.), gilthead sea bream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*), sole (*Solea solea*), and eel (*Anguilla anguilla*) are intensely caught. There are 5 barrier trap sets (Arapça 1 set, Karacagöl 1 set, Bölme 2 sets, and Kabahayıt 1 set) in the lagoon area. However, these traps lost their functionality due to neglect and also production is decreased (Figure 10). During the last production season when barrier traps were functional, percentage of production were occurred as 80 and 20% from fishing and barrier traps, respectively.

Figure 10. Little barrier traps of Akköy Lagoon

In order to increase productivity in the lagoon, old river bed was deepened and sea bass juveniles were released into here. Unfortunately, most of the sea bass died due to insufficient deepening and cold weather.

2.3.4. Legal Status

Until last tender session, although lagoon was managed by SS Söke-Akköy Fisheries Cooperative, it was rent and operated by the people in 2012. But, protocol was repealed due to non-payment of rental fee and ordered by district governorship to quit from the lagoon. Besides, insufficient financial support has caused to obstruct of investment for renovation and resulted non-functional of lagoon. In 2015, the firm has announced to end its activities in lagoon and also new tender session has been started to re-rent of the lagoon.

2.3.5. Sustainability

The depth of lagoon was 3-4 m in the past, now it is dramatically decreased due to shoaling. Half of lagoon area has 2 m depth and remaining part is less than this level. As observed in Karina Lagoon, main reason on shoaling is related with building drainage channels by channels built by General Directorate of State Hydraulic Works and changing of the Büyük Menderes River bed. The river bed of Büyük Menderes had been moved from between Bölme and Karacagöl Lagoon to north of Arapça Lagoon. This changing is caused to both shoaling and increasing of salinity in lagoon. Increasing of salinity strongly affected the primer productivity and caused decreasing of production for years. In addition to these, shoaling is obstructed water circulation and caused to increase of eutrophication areas in lagoon. Synchronously decreasing of water circulation and shoaling also caused to increase the vaporization effect and to expand of unproductive areas with high salinity.

In order to increase of productivity in lagoon, effective using of Büyük Menderes River is quite important. Water input to old river bed of Büyük Menderes is contributed to increase of productivity in the Kabahayıt, Bölme and south side of Karacagöl lagoons. Also, water transfer from the new river bed of Büyük Menderes is caused to increase of productivity of Arapça and north side of the Karacagöl lagoon. In addition to these, there is a necessity deepening of channels. With this operation, it is possible to connect the deepest points of north and south regions of Kabahayıt, Bölme and Arapça lagoons and control of shoaling. Also, it is thought that gradually increasing of productivity will be inevitable result after finishing of these operations).

2.4. Homa Lagoon

Homa Lagoon was investigated in five subheadings including general characteristics, social structure, production status, legal status and sustainability.

2.4.1. General Characteristics

Gediz Delta or currently called Izmır Bird Paradise which is located in Homa Lagoon and 25 km northwest of Izmir was formed approximately 2 million years. This delta reached to final form after seven times changing of bed of Gediz River which is along the 401 km. There are some marshes, salt pans, salt and fresh spring water, coves, and lagoons in mouth of Gediz River where 20.400 ha of 40.000 ha is wetland. According to Ramsar Convention, Izmir Bird Paradise (Gediz Delta) which is involving Homa Lagoon is "A" class wetland statue due to rich flora and fauna species. In 1998, it is added to list of Ramsar Convention and protected of 20.400 ha. Additionally, 8.000 ha of this site were accepted Wild Life Security Area in 1982, first degree archaeological protected area in 1999 and also marine borders were detected in 2002. Besides, there are some first degree archaeological protected areas in this delta (Gündoğdu *et al.,* 2005). Moreover, Gediz Delta has been included in to Area of Special Conservation Interest–ASCI after 2000 and some species required for protection were determined according to Barcelona Convention (Sönmez and Onmuş, 2006). In addition to these, in 2007 wetland management plan was accepted by the National Wetland Commission. With this plan, protection types were determined as "Absolute Protected Area", "Wetland Area", "Ecological Effected Area", and "Buffer Zone" and also protected according to Regulations for Wetland Protection (URL 4).

This delta is located Mediterranean Climate System and characteristics for Mediterranean vegetation is commonly observed in delta. Also, it is detected that 315 plant species are belong to 61 families. Two of these species (*Campanulalyrata subsp. lyrata* and *Stachys cretica subsp. smymaea*) are endemic. Especially, ling is located in south and its habitat is protected as primarily protected habitat type by the Regulations for Habitat of European Union. The most common species in delta are tamarix (*Tamarix smyrnensis*, *Phragmytes australis* and *Typha* sp.), common tule (*Scirpus* sp.), rush (*Juncus* sp., *Schoenoplectus littoralis*), duckweed (*Lemna* sp.), pine (*Pinus pinea*), eucalyptus *(Eucalyptus camaludensis),* mastic *(Pistacia lentiscus),* terebinth (*Pistacia terebinthus*), stinkbush (*Anagyris foetida*), oak (*Quercus coccifera*), dog-rose (*Rosa canina*), thorny burnet (*Sarcopoterium spinosum*), origanum (*Origanum onites*), asparagus (*Asparagus acutifolius*), and asphodel *(Asphodelus aestivus)* (URL 4).

Also, lots of animal species have been living in Gediz Delta. These mammalians which are fox (*Vulpes vulpes*), jackal (*Canis aureus*), wild cat (*Felis silvestris*), jungle cat (*Felis chaus*), cape here (*Lepus capensis*), wild boar (*Sus scrofa*), European badger (*Meles meles*), and least weasel (*Mustela nivalis*) living in different regions of delta. In addition to these, lizard and frog species are commonly distributed in the area.

Gediz Delta has very rich bird population and 291 species were recorded up to date. During the year, about 235 bird species could be easily observed. Also, flamingo

(*Phoenicopterus roseus*), Dalmatian pelican (*Pelecanus crispus*), little tern (*Sternidae* sp.), Kentish plover (*Charadrius alexandrinus*), spur-winged lapwing (*Vanellus spinosus*), and Mediterranean gull (*Ichthyaetus melanocephalus*) are commonly spawn in this area. Gediz Delta is one of the spawning areas for flamingo with Tuz Gölü in Turkey. Also, this is one of the most important spawning and feeding area for endangered species, Dalmatian pelican (*Pelecanus crispus*) and the single field in Turkey for spawning of sandwich tern (*Sterna sandvicensis*) (Sönmez and Onmuş, 2006).

Loggerhead sea turtle (*Caretta caretta*) and green sea turtle (*Chelonia mydas*) spawn along the coast of the Mediterranean and Aegean Sea, however, it is reported that they could be observed for spawning sea side of the delta and Izmir Bay. European pond turtle (*Emys orbicularis*) is distributed wetland area and ditches however it is endangered species around the world. Also, spur-thighed tortoise (*Testudo graeca*) is usually live in grassland and wetland fields (Sönmez and Onmuş, 2006).

Gediz Delta is a rich area with regard to aquatic animals. For instance, loggerhead sea turtle (*Caretta caretta*) frequently enter to Izmir Bay and reach to coast of delta due to abundance of food. In similar with, Mediterranean monk seal (*Monachus monachus*) which is one of the rare animals around the world is occasionally reach to these coasts for feeding. Along the coast of delta and lagoons, total 60 marine fish species and also total 14 fresh water species around the mouth of Gediz River and Sazlıgöl Lake were determined. Not only importance of ecological equilibrium but also economic value, most of the fish species are important for the people living there.

Homa Lagoon is the biggest lagoon in the Izmir Bird Paradise. Homa means soil and this name is originated from the soil sets which are separated lagoon and sea. Homa Lagoon is one of the most important wetlands area is located northeast side of the Izmir Bay at 26° 48’ 81’’ and 26° 53’ 31’’ east longitude and 38° 30’ 58’’ and 38° 35’ 36’’ North altitude (Figure 11).

Homa Lagoon is located between Çamaltı saltpan and Gediz River and also consists of two main parts. These are Homa (main lagoon) and Kırdeniz (small lagoon) Lagoon. The main fisheries operations are usually carried out in Homa Lagoon and it has 7.4 km length, 3 km width and about 1.200 ha. Also, Kırdeniz Lagoon is smaller than Homa and it has 3.4 km length, 1.2 km width and about 600 ha. The total area of lagoon is 1800 ha (Acarlı *et al.,* 2009; Atılgan and Egemen, 2001). Kırdeniz Lagoon has lost the main features of lagoon due to alluvial deposit from the Gediz River. Also, there are approximately 300 ha shoaling area in the Homa Lagoon (Atılgan and Egemen, 2001).

Figure 11. Location of Homa Lagoon in Turkey and Aegean Sea.

The average and maximum depth of the Homa Lagoon are 40-45 and 80 cm, respectively. During the summer, salinity sharply increases to around ‰70 level and caused top damage on ecological equilibrium due to straitening of channels and reduction on introduction of fresh water. The average salinity level of the lagoon was changed from 27.49 ‰ to 38.61 and the highest peak was reached to 73.12 ‰. Also, water temperature and pH were fluctuated between 11.2-31.3 °C and 7.45-8.10, respectively (Önen, 1990; Kutlu and Büyükışık, 2007). The annual seston level was determined as 30.9-274 mg/l in the lagoon. Besides, concentrations of ammonium, nitrate, nitrite, phosphate and reactive silica were 2.53-62.58 µg-at l^{-1}, 0.62-5.12 µg-at l^{-1}, 0.12-1.76 µg-at l^{-1}, 0.18-3.14 µg-at l^{-1}, 0.15-1.76 µg-at l^{-1} depend on nutrient measurements (Yaramaz and Alpbaz, 1988).

In benthos, total 58 species were detected in lagoon. The first one is Polychaeta (28 species, 48.3% abundance) and also followed by Crustacean (15 species, 25.9% abundance), Mollusca (11 species, 18.9% abundance) and Diptera (1 species, 1.7% abundance), larvae (Önen, 1990). Additionally, total 65 species, in detail 15 species of Gastropoda, 1 species of Cephalopoda, 10 species of Crustacean, 2 species of Chondrichthyes and 37 species of Osteichthyes were determined. In Osteichthyes, 28 of 37 species (%75.67) were economic. Moreover, pipefish (*Syngnathus abaster*) is accepted as endangered species (IUCN, 2009).

Homa Lagoon is seriously influenced by the natural and anthropogenic effects. Until 2000, the Gediz River usually transported high concentrations of metal due to the inputs of textile, pigment, metal plating, beverage and paper factories and domestic wastes to the outer part of the bay. Furthermore, this lagoon was negatively affected pesticides by agricultural drainage from the Menemen plateau.

2.4.2. Sociological structure

Gediz Delta is surrounded (west, south and northwest) by the Aegean Sea and also elongated from Karşıyaka-Mavişehir to Menemen at northeast and Foça-Bağarası at northwest direction.

In 1991, fishers in these towns established S.S. Sasalı and Adjacent Towns Fisheries Cooperative and reached to 240 members. In these towns, the population is about 9.000 and fisheries efforts mainly carried out spring and summer.

2.4.3. Production Status

Homa Lagoon is the important due to only active lagoon in the Izmir Bay. Usually, after fish entering to lagoon the main channel is closed in June in order to hold of the fish inside of lagoon area. Traditionally, barrier traps, gill net, trammel net with reed and fyke nets are usually used for fishing. It is reported that grey mullet (*Mugil cephalus*), leaping mullet (*Liza* saliens), thinlip mullet (*Liza ramada*), golden grey mullet (*Liza aurata*), and thicklip grey mullet (*Chelon labrosus*) the main species of Mugilidae family are usually caught in the lagoon. In addition to these, gilthead sea bream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*), sole (*Solea solea*), eel (*Anguilla anguilla*), white sea bream (*Diplodus sargus*), stripped sea bream (*Lithognathus mormyrus*), flounder (*Platichthys flesus*), red mullet (*Mullus barbatus*), stripped red mullet (*Mullus surmuletus*), turbot (*Scophthalmus rhombus*), annular sea bream (*Diplodus annularis*), two-banded sea bream (*Diplodus vulgaris*), needlefish (*Belone belone*), tub gurnard (*Trigla lucerna*), marbled goby (*Pomatoschistus marmoratus*), big-scale sand smelt (*Atherina boyeri*), European pilchard (*Sardina pilchardus*), anchovy (*Engraulis encrasicholus*), rusty blenny (*Parablennius sanguinolentus*), blenny (*Blennius spp.*), cuttlefish (*Sepia officinalis*), greater pipefish (*Syngnathus acus*), broadnosed pipefish (*Syngnathus typhle*), Mediterranean killifish (*Aphanius fasciatus*), and shrimp (*Penaeus kerathurus*) are caught by barrier traps in the lagoon (Özden *et al.,* 1994; Akyol, 2005; Kara *et al.,* 2009; Acarlı *et al.,* 2009). In 1998, So-iuy mullet (*Mugil soiuy*) was firstly reported but after this date no fish had been caught in barrier traps. Fishing has been currently continuing from 2 barrier traps in the Homa Lagoon (Figure 12).

Figure 12. Homa Lagoon and barrier traps.

The total percentages of Mugilidae and sea bream production are approximately 70 and 25%, respectively. The remaining 5% is consisting of the other species. Also, caviar production is changed between 100 and 150 kg per production season. Total production of the Homa Lagoon is gradually decreased year by year. Annual production was around 70 tons in 1980's but it decreased to 20 tons in 1990's and after this year declined to 5 tons per year. There is no production during the last three years in this lagoon. After completing of the remediation and deepening operation of the Homa Lagoon, it is planning that new protocol will be approved and restarted to production in 2016.

Izmir Municipality and General Directorate of Natural Estate and the lagoon management was allocated to Ege University, Faculty of Fisheries. After his date, several projects, scientific studies and fishing efforts were conducted by the university-cooperative cooperation in the lagoon (URL 5).

Due to reduction of productivity and damage by the strong currents in lagoon, renovation and remediation studies have been started by Izmir Municipality in 2009. In this sense, barricade and service road between sea and lagoon has been established. It is thought that damage by sea can be minimized by force of barricade. During this study, some non-governmental environment organizations objected to General Directorate of Cultural and Natural Heritage due to using of excavation for prevention of the barricade. Then, some detailed plans were prepared by Ege University and presented to General Directorate of Cultural and Natural Heritage for permission. After this step, according to "Homa Lagoon Rehabilitation Project" renovation and remediation studies have been re-started by Izmir Municipality and Ege University.

2.4.4. Legal Status

Over the past three decades, although Homa Lagoon is one of the most productive lagoons in the Aegean region, no investment and remediation were carried out, became more neglected and disorganized due to ambitious enterprises and unexpected lawsuit. In order to renovate and remediate of the lagoon, both Ege University, Faculty of Fisheries and fisheries cooperative started to work synchronously in terms of education, research and fishery. Currently, several projects, scientific studies and fishing efforts are continued by the university-cooperative cooperation in the lagoon.

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2.4.5. Sustainability

At the end of the 19th century, the bed of the Gediz River was changed in order to prevent of the Izmir Bay from alluvial deposit of mad and in present it reaches to the Izmır Bay from the north side of this protected area. Nowadays, the other lagoons - Çakalburnu, Ragıppaşa and Çalıburnu- are not active however there is still production in the Homa Lagoon. This situation is enhanced of lagoon popularity and thus strongly makes a topical issue about necessity for prevention and saving of it. After 1990's, production of Homa Lagoon was dramatically decreased due to lack of fresh water, since fresh water channels of lagoon was dogged for reduction of salinity in the field by General Directorate of State Hydraulic Works, this caused to stop of introduction of fresh water to lagoon area.

As stated above, barricade and service road between sea and lagoon has been completed and commenced service in 2012. The second project which is related with improvement and rehabilitation of the Homa Lagoon and Izmir Bird Paradise area is prepared and required legal permissions have been received from the official organizations and studies started in 2014 and also still continued (Figure 13). For this project, special Machine Park is established for the first time and it would be an example for renovation and remediation studies for the other lagoons.

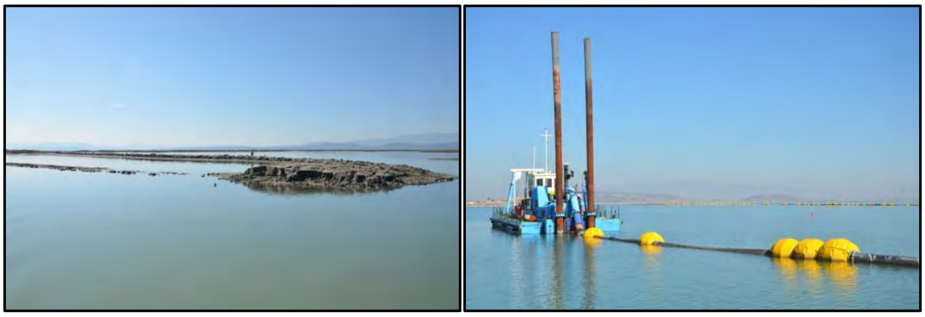

Figure 13. Improvement and rehabilitation of the Homa Lagoon

3. Conclusion

Coastal characteristics and freshwater resources in the Aegean region are caused to several lagoons during the geological ages. According to Agriculture Industrial Project in 1997 there were 29 active lagoon but they decreased to 10 and 5 at 2000 and 2015, respectively. It is thought that the main reasons for the reduction of the number of active lagoon are destruction of the natural structure, lack of management, relations between cooperative and governmental organizations and non-modernizing of traditional methods.

Freshwater is usually obtained from the adjacent rivers and transferred by the main drainage channels which are established by the General Directorate of State Hydraulic Works. Although these channels have an important role for prevention of floods, they play major role in shoaling of the lagoon. This case is discussed in detail under the heading of sustainability for all lagoons in this text.

The freshwater mainly enter to Karina and Akköy Lagoon from the Büyük Menderes River and also pass to Güllük Lagoon from the Sarıçay River. In these area, freshwater usually used for agriculture but remaining of water is transferred to drainage channels and/or river branch thus reached to lagoon. Therefore, the possibility of the pesticide presence in the returned water is significantly increased. In order to control of this case, it is important that some chemical analyses should be carried out in terms of organic and inorganic pollutions and also water flow rate should be adjusted seasonally.

One of the most important problems of lagoon area is illegal hunting due to huge area and difficulties for control. It is determined that illegal hunting is observed in several times in the most of the lagoon. Although fish are captured from lagoon in legal size, most of them are not reaching to marketable size thus they are sold below real economic value. Besides, it is not possible to release of capture fish to lagoon area. The main reason of this case is that lagoon area is usually shallow and extremely cold which is caused to mortality of fishes. Hence, establishment of deep wintering ponds, husbandry of fishes until marketable size will play a major role for increasing of income of lagoon.

It is commonly known that fish are intensively caught from the barrier traps during the production season thus they are usually sold cheaper than real economic value. In order to prevent this case, it will be better to establish and/or to hire a cold storage depot. With this solution, it will be possible to sell controlled of whole fish. In this sense, income of lagoon will increased substantially without increasing the amount of production.

Fish in lagoon is usually following the currents flowed from the sea and direct to barrier traps. Thus, fish are caught in these traps while swimming to sea due to closed of main channels of lagoon. Barrier traps are usually worked as one way system therefore fish are captured on the line of the sea. In contrast to this, it is not possible to enter any fish from the sea to lagoon area during the water flowing from lagoon to sea due to closed of main channels. In order to prevent this case, bidirectional barrier trap systems are designed in the past decade. Thus, fish are easily caught in these traps while they entering from the sea to lagoon area. Therefore, establishment of bidirectional barrier trap systems is the crucial step for enhancement of production in lagoons stated in this chapter.

Cooperatives are based on a specific model which is usually aimed to progress commercial relations and community development. They generally works dynamic, fairly and democratic and also based on some principles such as self-sufficient, self-confident, self-responsible, serving for partners, ownership of partners, and management by partners. However, management of some fisheries cooperatives in lagoon area which earn relatively lower gain and not working throughout the year are considerably difficult. It is necessity to expand profitably of the gain for one year in spite of earning during the three months. Unfortunately, no highly experienced managers were in the Karina, Akköy and Güllük Lagoons. In Karina Lagoon, management of cooperative has been living hard times in the recent years for solution of economic problems. In addition, Akköy Lagoon has not been rent due to high economic crisis of cooperative. Similarly, it was not possible to make a tender for fisheries in lagoon area thus not lagoon was not rented by cooperative due to management problems. In contrast to these, Homa Lagoon has been managing by Ege University more than two decades. Therefore, it is thought that management of these lagoons by the highly experienced and educated managers is inevitable obligation.

It is clearly estimated that routine errors related with production method, process technique of product, marketing, and control are made in all lagoons in the Aegean Region. In this chapter, not only some mistakes were revealed but also solution methods were determined. The sustainability of the lagoons is important merely for the regional fishers but protection of endangered and threatened species as well. Furthermore, it is approved that these areas are natural wealth for the country in terms of biological diversity. Briefly, there areas could be accepted both indispensable economic reserve to sustain of their life of people and also natural habitat for animals who are living these regions. As a result, lagoons are clearly assurance and indispensable feature not only welfare of people in future but also biological heritage should be transferred for the next generations.

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AQUACULTURE IN THE AEGEAN SEA

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1. Introduction

Turkey has an important potential on aquaculture as in fisheries from adjacent seas. Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. Aquaculture has been the world's fastest growing food production system for the past decade.

Aquaculture production, supply nutrition of the people and create employment for raw material to the industrial sector, significant opportunities in matters of preservation of biological diversity with rural development contributing to the high export opportunities and more effective management of natural resources. Studies on marine finfish culture were increased after 1980's. This situation was parallel with aqua cultural developments in especially Mediterranean countries. Aquaculture sector in Turkey developed in a specific period until 2000 and the current output reached 79031 tone/year. The several economic crisis that Turkey experienced played an important role here. With aquaculture, output tended to increase in 2003. Some factors such as the recovery of economy, Turkey's progress in EU full-membership and financial aid of the state to the sector affected the growth (Tacon *et al.* 2010).

Research results indicated that the the country's aquaculture potential is about 1 million tons.

2. Historical and Current Perspectives

Aquaculture has a history of 4,000 years, but it is only in the last 50 years that it has become a socioeconomic activity of importance, giving employment to 9.8 million people around the world (FAO, 2000). Its contribution to the world's fish, crustacean and mollusc supply is growing every year. According to FAO, contribution of aquaculture to world supply has increased from 3.9% of the total fishing production (in weight) in 1970, to 29.9% in 2002, with a forecast of 50% in 2025. However, in 2006 aquaculture already provided almost half of fishing products for direct human consumption. (FAO, 2007)

The first regulations on the management of fisheries in Turkey enacted in 1867, began with the legislation regulating the export mussels and oysters. In 1934, established a Directorate attached to the Ministry of Fisheries and Marine Products, the directorate has been transferred to the Ministry of Transport in 1939. For the first time a comprehensive fisheries legislation (Law No. 1380) in 1971 issued a separate until the General Directorate of Fisheries has been established. General Directorate of the Directorate of Fisheries are founded in 1971 and Aquaculture services were managed in this unit until 1982. The revised organizational structure of the Ministry of Agriculture, Fisheries and Aquaculture Department of the General Directorate formally put an end and it has been reduced to the department level in 1982. A new arrangement of Fisheries made in the organizational structure of the Department divided the Presidency's tasks as General Directorate of Project Implementation and the General Directorate of Protection and Control in 1984. Agricultural Production and Development, Protection and Control was conducted by the Agricultural Research and the Directorate General of Organization and Support as dependent on the new regulations, aquaculture services in 1992. Issued in 2011 639 numbered Decree of the Ministry of Agriculture and Food was reorganized as the Ministry of Agriculture and Livestock and Fisheries and Aquaculture General Directorate has been established.

The first aquaculture practices in Turkey regarding the Abant Lake trout farming in the years 1956-1957 Istanbul University Faculty of Science, was conducted by the Hydrobiology Research Institute. Restocking for the first time to fish the lake again in 1958 by the Institute of Hydrobiology Research was conducted in Marmara Lake Egirdir Lake. The first carp and trout rearing practices in Turkey began to find life in the years 1958-1965.

Sea bream and sea bass farming practices to the nature of the Aegean Sea began to concentrate on juvenile fish collection practices since 1985. The same year, the first example of investment in our country engages in seafood farming in Pınar Inc. Ildırı/Çeşme-izmir. It was carried out by. Realization of mussel farming for the first time in Çanakkale (Gallipoli) in Turkey in 1980, by Marsan Inc.

For many years, the collection of wild seeds or juveniles has been practiced worldwide in order to stock them in aquaculture facilities for ongrowing purposes. The collection of adult organisms is a special case related to the construction of captive broodstock used for breeding in hatcheries. The collection of adults is not so important quantitatively, except in recent cases of fattening, such as commercial bluefin tuna farming. In our country, the activities began opening the first bluefin tuna farm in 2002. Tunas for 6-8 months, feeding on fish such as mackerel herring, and sardines are lubricated and are exported all over the world, including Japan first ship with special systems to freeze in December and January. Especially on the bluefin tuna export market in Japan it has a very important place.

Current situation

Turkey's coastal resources for aquaculture are exceptional. A wide diversity of aquatic species can be farmed in brackish or salt water using a variety of production systems. Today marine aquaculture plays an increasingly important role in the production of fishery products. Aquaculture with a relatively short history in Turkey began with the farming of rainbow trout (Onchorhynchus mykiss) and common carp (*Cyprinus carpio*) in the late 1960s and developed further with gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) culture in the mid-1980s.

After first establishment in 1984, the number of marine fish hatchery sharply increased and reached 21–unit in 2001. But, the biggest re-organization was occurred after 2008 economical crisis, because little-scale hatcheries were sold out Greek enterprises due to great unemployment and dramatically reducing of commercial gain in aquaculture sector.

Turkey's total catch and total production of bluefin tuna, was 527,5 and approximately 2500 tones respectively in 2011. But, in order to enhance of production, Turkish enterprises usually buy the adjacent countries' bluefin tuna quota. The main market is Japan as frozen, fresh and chilled full body of tuna. On the other hand, according to TurkStat data, bluefin tuna of 325 tones was imported and also 1950 tones were exported (Table 1) (TurkStat, 2011).

In Turkey, the intensive farming of seafood is concentrated in the Aegean Sea, İzmir-Antalya coast. Aquaculture has made rapid progress during the last two decades in Turkey.

Aegean Sea specifications:

Coastline: 2805 km

- The seawater temperature : 10 to 22°C in the north, 16 to 25°C in the south
- The salinity is relatively stable: 36 and 38 ppt.

Direct kind of rates 1/400 of economic importance in the world's seas while in the Aegean Sea, this ratio is around 1/50. The majority of marine fish business presence in the Aegean and their suppliers are particularly advantageous in terms of production of marine fish in Turkey.

Table 1. Quantity of fisheries production in Turkey (TurkStat, 2014).

Quantity of fishery products, 2014

(**Ton** - Tonnes)

	2013	Share (%)	2014	Share (%)	Change (%)
Fishery products	**607 515,2**	**100,0**	**537 344,6**	**100,0**	**-11,6**
Fishery products by catching	**374 121,3**	**61,6**	**302 211,6**	**56,2**	**-19,2**
Aquaculture	**233 393,9**	**38,4**	**235 133,0**	**43,8**	**0,7**

TurkStat, Fishery Products, 2014

2014 as marine fish culture in this point: the nature of juvenile fish collection practices has remained in the background, still about 400 million fry with 19 special 2 Ministry hatcheries working with modern technology / year reaching capacity. In 358 units' marine fish production the company realized 115 360 tons, the country contributed a total of $ 520 603 300 and thousands of people directly and indirectly creating employment opportunities for the sector (Table 2).

Since 2013, our country has taken the first place in salmon production and the third place in sea bream and sea bass production among European countries. Our export of water products sector tends to go up constantly and it has ended in 512 million dollars since 2013; and one out of every three fish commercialized to European countries springs from Turkey. The latest situation in mariculture shows this sector in our country has been growing by being backed by developing technology.

Number of farms and Production Techniques

- Total number of farms: 1300
- Farms in inland waters: 500
- Farms in marine waters: 358

Although the number of fish farms operating in the seas constitute about 1/5 of the number of fish farms in inland waters, which seems to be almost the same capacity when the project. Another point is about using the entire capacity of a large part of the project company active in the marine, inland waters are lower capacity utilization. However, capacity utilization in the inland waters began to be seen large increases in recent years. Given the scale of the operation, 36% of the businesses found in the sea in number of 250-1000 tonnes / year it seems to be fish-producing enterprises. When capacity taken into consideration, 52% of 250-1000 tons / year is capacity. 1000 tons / year above the percentage of businesses with 33% of capacity. Because of these indicators are not clear and deep water production in the farms raising seafood in recent years reveals that they expanded their maximum capacity.

Table 2. Quantity of aquaculture production in Turkey (TurkStat, 2014).

Aquaculture production, 2014					(Tonnes)
Type of fish	2013	Share (%)	2014	Share (%)	Change (%)
Total	233 393,9	100,0	235 133,0	100,0	0,7
Sea					
Trout	5 186,2	2,2	5 610,0	2,4	8,2
Sea bream	35 701,1	15,3	41 873,0	17,8	17,3
Sea bass	67 912,5	29,1	74 653,0	31,7	9,9
Other	1 575,3	0,7	4 758,0	2,0	202,0

TurkStat, Fishery Products, 2014

In our country, the intensive farming of seafood is concentrated in the Aegean Sea, Izmir-Antalya coast.

Table 3. Mariculture production in the Aegean Sea (TÜİK & BSGM, 2012)

Provincial	Species	Quantity/Tonnes
Aydın	Gilthead Sea bream	73
Balıkesir	Gilthead Sea bream	12
	Sea bass	15
İzmir	Gilthead Sea bream	7450
	Sea bass	14865
	Mussel	125
	Others	1385
Muğla	Gilthead Sea bream	19860
	Sea bass	33358
	Others	816

According the legislation in force there are a necessity distance from the coast at least> 1,111 meters (0.6 miles), depth> 30 meters, current Speed> 0.1 m / s. for fish farms (Anonym, 2007).

Aquaculture producer organizations particularly in the aquaculture sector grower's association accordingly Unions Aquaculture Muğla and İzmir, including manufacturers Central Union role plays. Adopted in 2004 5200 No. Agricultural Producers' Association it was founded in January 26, 2009 based on the law. There are 16 affiliated to the Central Association of the Union.

3. Overview of Aquaculture Methods and Practices

Currently, intensive aquaculture in net cages at the seas, reservoirs and in lakes, concrete ponds and fiberglass tanks in intensive farming, ground ponds and ponds in semi-intensive system, in closed-circulation system and farming are mainly current systems used for aquaculture in Turkey. Moreover, ground-ponds, concrete tanks, cages in inshore, semi-offshore or offshore conditions, respectively are also other methods used for the aquaculture production. (Table 3 and 4).

Larvae Production and Hatcheries

Fish larvae production have been significant developments in recent years. Prohibition of capture from nature, because it has increased the number of hatchery with import is expensive and hard (Figure 1). These are modern enterprises, automatic water quality control and feeding systems in use and production of fry out of season (photoperiod application) they do.

To abandon the completion of the embryological development of eggs and egg capsule is passed along with the larval stage. The name of prelarvae is given newly hatched eggs to these creatures.

Immediately after the absorption of the food sac postlarvae stage begins and continues until the end of the formation of organs. At this stage, the diet is completely with feed from outside.

The end of formation of the scale that postlarval period and determines the beginning of juvenile cycle.

Table 4. Fish larvae production for provincial in Aegean Sea (TurkStat, 2014).

Provincial	Hatchery Number	Total capacity/ Number Million Fry
Muğla	5	212
Aydın	3	215
İzmir	6	128
Çanakkale	1	40

Sea fish are still operating in our country in order to produce 595 million number / year capacity to produce fish fry has 15 hatcheries.

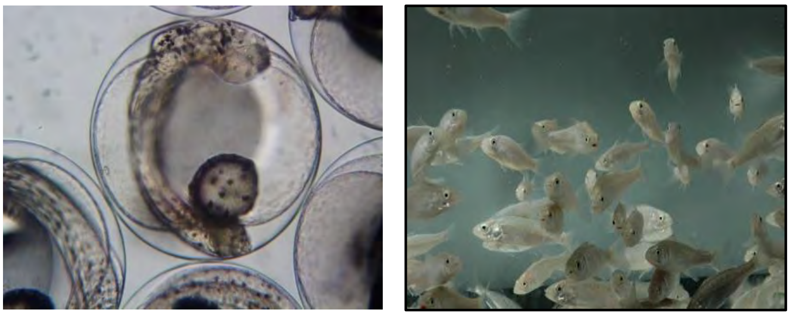

Figure 1. Embryonic and juvenile stages of the sea fish

Aquaculture is also a question as industries providing input feed to the aquaculture industry outside. Especially aquaculture unit of the instruments and supplies (tanks, cages, barge, filter, ships, etc.) production or supply undertaking and an industry group supporting the infrastructure and systems to the sector. The big majority of these are provided by local structures.

Marine cage culture

Especially in recent years, enormous progress recorded in the aquaculture system, especially in medium and large enterprises began to use modern and advanced technologies. Open deep waters to move on in this which makes compulsory marine fish farms the use of convenient new techniques aquatic environment, both in size and structure of cages, in both the mooring system began to be used in aquaculture more advanced technology from countries have a say. The barge systems and automatic feeding units facilitated by the introduction of the provision of logistics support, protection and monitoring mechanisms were created digitally. In terms of systems used in the hatchery were very large distances parallel to the development of infrastructure as well as industrial and technical terms of strides forward in this regard were laid.

According to the state of the cages and water quality characteristics of the place where the establishment of 10-30 kg / m3 storage can be done. The depth of the cages varies depending on the cage type. At the 2-3 years, place of a cage to protect the quality of the seabed under the cages should be replaced. Prevention of diseases, there must be also spaced from plants and water quality in terms of visual effects. Good nutrition is a result of market size in 18 months 370-420 g sea bass, sea bream reaches market size of 250-300 g in weight within 16 months.

Cage construction materials;

Wooden cages: Net bag dimensions of 5 × 5 × 5m in wooden cage. The net volume of 125 m^3. Corner connections are provided using metal alloys (Figure 2). Wind direction and currents among the issues to be considered binding in the cage is important.

Figure 2. Wooden cages used in Turkish fish farms

Metal Cages: metal cage dimensions of 15 × 15 × 10 m. size. Such cages are more resistant to the offshore system (Figure 3).

Figure 3. Metal cages used in Turkish fish farms.

Polyethylene cages: Ideal as a strong material used in the cage, lightweight, corrosion and weather resistant, biofouling resistant, easy to perform and can be repaired, appropriate structure and asked to be cheaper to prevent damage to chemical-free fish(Figure 4). This width of 5-10 m cape are cages 14-30 m depth network. Suitable cage these properties is observed that more widely used in recent years. Except that wooden crates may be hexagonal or circular frame. It must be at least 15m maximum depth of 45m. (Beveridge, 1996, Beveridge *et al.*, 2010).

Figure 4. Polyethylenes cages used in Turkish fish farms.

Development of Cage Culture
First Period 1984-1993
• Nature of juvenile fish collection • Simple to use mechanization • Irresponsible production activities • Technical information failure • inadequacies in infrastructure facilities • High profit forecast • rapid rise in the number of Business • Low production capacity (Figure 5)

Figure 5. A view of cage farms during the first period.

Second Period 1994-2003
• Success in fry production • Quick capacity increase • standards required of businesses • The impact of the economic crisis • Knowledge and use of technology (Figure 6)

Figure 6. A view of cage farms during the second period.

Third Period 2004-2013

• Numerical decline in business • Rapid increase in production capacity • Product quality promotion • Food security and branding • Increased knowledge and use of technology • Specialization and alternative production strategies • The expansion of R & D activities (Figure 7).

Figure 7. Cage farms during the third period.

4. Culture Species and products

Mainly farmed species in the Turkish coast of the Aegean Sea are ; Sea bream (*Sparus aurata*) Sea bass (*Dicentrarchus labrax*), Common seabream (*Pagrus pagrus*), Common pandora (*Pagellus erythrinus*), Axillary seabream (*Pagellus acarne*), Red banded sea bream – (*Pagrus aurige*), Sharp-snout sea bream – (*Puntazzo puntazzo*), White sea bream- (*Diplodus sargus*), Shi drum- (*Umbrina cirrosa*), Common dentex (*Dentex dentex*), Bluespotted seabream-(*Pagrus caeruleostictus*), Northern bluefin tuna (*Thunnus thynnus*), Shrimp (Penaeidae spp), Mussel (*Mytilus galloprovincialis*) (Figure 8).

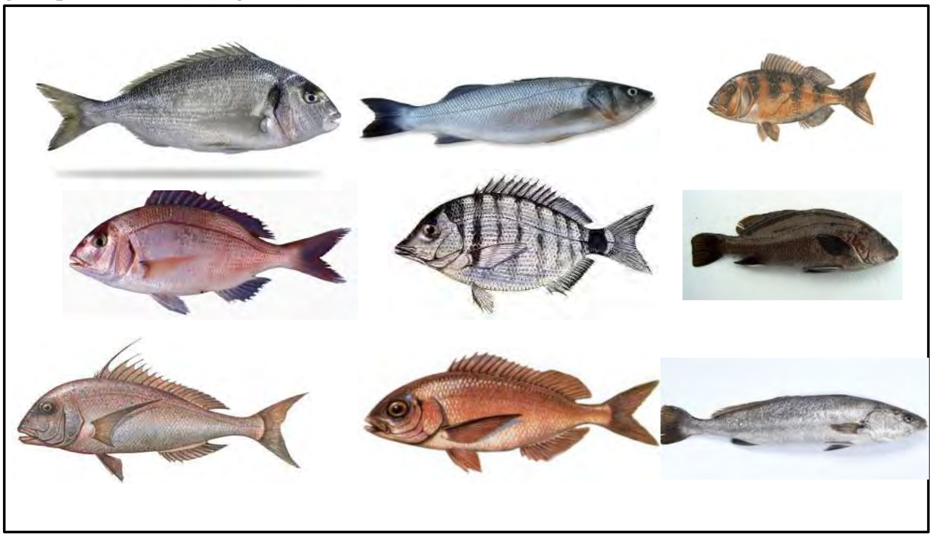

Figure 8. Overview some of farmed species sea fishes. *(Sparus aurata, Dicentrarchus labrax, Diplodus puntazzo, Dentex dentex, Argyrosomus regius, Dentex gibbosus, Pagrus pagrus, Sciaena umbra, Pagrus aurige.)*

5. Marketing

84% of the sales of seafood was done by brokers (middlemen, traders) and in Turkey. The remains 16% are selling as follows; 7% to the fish meal factory (in the Black Sea region only), 3% to the cooperatives and associations, 3% to the directly consumer, and 1% cannery, 2% while the portion of their consumption (self-consumption).

6. Sustainability and Problems

There are two key components of sustainability. The presence of a source, manage and protect these resources for the future. Aquaculture facilities in Turkey, shows the diversity of the aquaculture sector in a very non-pretentious facilities to small-sized industrial enterprises to compete in global markets. Aquaculture is a rapidly growing sector and is also active in other parts of the world. Aquaculture industry, coastal waters and in use with other industry partners, and as a result, comes inevitably confronted with other users. Different ministries declared as uncoordinated in their subject area, have made a prospective study to ensure the integration of planning or failure to follow studies has led to the removal from each of the different sectors. (Anonym, 2006).

Every use nature to create environmental impact is also affected by environmental factors. Therefore the culture fish farms can now be installed in an area far from industrialization and settlement. Environmental issues affecting the aquaculture industry, waste and waste, leakage, diseases and parasites, chemicals are listed as nutrition and food. However, studies in the list where the aquaculture is industrial and household waste pollutes the sea within the factors indicate the last time (Pillay,1992). According to a scientific study conducted at sea by TUBITAK, the fish farm as their position that the sea water in the physical, chemical and do not cause significant changes in the biological sense, pollution is a threat in terms of risk.

One of the elements of sustainable aquaculture production of the product is to create diversity. In case of saturation in the market to create the kind of intensive production is made to enter the market with alternative product solutions. Create new markets to increase their promotional activities in this sense, it is important to expand the market area. Aquaculture sector is seen as the sectors of the future all over the world, and is being supported to ensure the sustainability of development policies. The same approach should apply in this sector of our country.

Fry and feed in aquaculture comes first in the most important inputs. Our country is unable to perform the 500 million marine fish fry production and hatchery capacity currently available. Therefore, it is considered to sustainability in the short and medium term the entry of juvenil fish. However, more extensive studies must be done in terms of providing the fry in breeding of new species in economic terms.

Aquaculture activities attract the reaction of the public from time to time, on the grounds that they are not required to fish farms pollute the water unconscious and with prejudice. Competition in the sharing of natural resources, environmental non-scientific attitudes, conflicts of interest to further improve response, this response carries frequently raised in the media organizations. The inability to adequately light the public sector and in the sector of scientific institutions, the negative approach in the absence of sufficient efforts in this area is the fact it may take in the future.

Currently, aquaculture related priority research fishery products between the topic of genetic resources and protection, fish health management and welfare.

7. Examples of the aquaculture enterprises in the Aegean sea

7.1. Biggest aquaculture company; Kılıç Holding

It started production in Salih Island as the personal enterprise of Orhan KILIÇ with 50 tons of capacity at the 1991.Today, the biggest aquaculture capacity in Europe and 40.000 ton aquaculture capacıtıes for sea bream, sea bass and trout (Figure 9). Sea bream and sea bass fingerlings, produced in hatcheries in Bafa, Oren, Akarca and

Guvercinlik of Kılıç Deniz, are settled to 20 m-dia-HDPE cages by transporting into fingerling plants in cage establishments when they reach to 3 – 5 kg weight. Fingerlings are fed with 5-8 times depending on the water temperature. From the fingerlings reaching to 30-40 gr weight after a great attention, sea breams are transported to 30-50 meter-dia-HDPE cages equipped with special nets for them. And then, they are sent to growing plants. This process is performed to remove the size difference, which may be come out in the future, and to provide a healthy growing. Due to the fact that sea bass is more sensitive to diseases than sea bream, they are vaccinated one by one with the injection method when they reach to 30-50 gr. After this process, they are measured, counted and transported to 30-50 meter-dia-HDPE cages. And then, they are sent to growing plants as sea bream.

All of the growing plants are off-shore system. The units have technology using automatic feeding systems and underwater and surface cameras. Both underwater and surface controls are performed in this system by experienced engineer, diver and experts with a great attention and self-devotion.

As different species, the production of dentex, common sea bream and another breams has been started and these fishes have been represented for markets. Feed Factory within Kılıç Deniz group.Sea bass reaches to portion size for 16 – 22 months and sea bream reaches to this level for 13 – 14 months (Figure 10). They are sent to packaging plant within the holding to present for markets.In cage establishments, all the transactions, from the hatchery to packaging stage, are recoded and the fishes are monitored in all systems. Kılıç Deniz Cage Establishments assumes a principal to follow the environment regulations, to keep the effects for environment pollution under control and to decrease this pollution and harm into minimum level. These establishments hold certificates of ISO 14001 Environment Management System.

Figure 9. General vue and adaptaion unit from Bafa plants.

The biggest capacity of the World in the production of fingerlings. Kılıç Deniz, began trial production of seabream and seabass fingerlings in 1997 year with 4 million units / year capacity in Ören Kuluçkahane Facility, is the world's leading company capable of producing large bream and sea bass fry. Kılıç Deniz has an annual production capacity of 320 million fingerlings as of 2012. Kılıç Deniz exports an increased amount each year a portion of fingerlings for 3 years. Exported and operating countries are respectively Greece, Tunisia, Morocco, Egypt and the United Arab Emirates. As well as a large of fleet vehicles is used for the aim of transport of living fingerlings, 2 pieces of fingerlings in 28 m and 42 m. Many new projects have been implemented with R & D co-operation of the Project Development and Production Units,. Some of the projects move to implementation phase with the intensive studies. Besides Projects are operated with universities in co-operation of "Industry-University", they are continued common research collaborations within EU too. R & D Works are bio-technological studies mainly related to the production of new species of fish as well as existing business development. Except for the production of sea bream and sea bass dentex, common sea bream, bream, striped sea bream, bream, minnow, yellowtail, mullet, meagre, sharpsnout, laos, shield, participated the production on a commercial scale. Still in a dense shield, sturgeon, mullet, meagre fish production is underway. In the following years it is planned to increase production volume.(url 1).

Figure 10. Growing systems offshore and open sea cages.

Kılıç Holding, from hatcheries Bafa, Oren and Guvercinlik operating in, from bream and perch fry from about 3-5 g for the young plant operating in the cage; 20-30 m diameter cages are placed in HDPE. Sea bream from fry brought to about 30-40 g range of future sorted in order to be able to turn off that can occur size differences and ensure healthy growth are individually counted and 30-50 m in diameter, the network produced specifically for the sea bream being transferred to that HDPE cage installed, it is sent to after enlargement facility. Sea bass was they are more susceptible to sea bream or by disease, 30-50 grams are inoculated individually with the injection method while weighing and counting is classified after the application are transferred to 30-50 m diameter HDPE cage and still is drawn to the magnification facility. In addition, it is regulated to each of fingerlings “Certificate of Vaccination". Facilities of fingerlings production, awarded with the ISO 9001 Certificate of Quality Management System in 2005, are proved of quality.

Figure 11. A barge and offshore cage farm of Kılıç

All of growing facility is offshore systems; automatic feeding systems and water are units with the latest technology used in the six-camera above water. Seabass are 16-22 months; sea bream and 13-14 months of the end portion size to reach the market, is sent to the packing facility in again holding (Figure 11).

Changing fry production capacity compared to the year 2010 are as follows:
* Ören hatchery; 20 million bream, perch 20 million, 6 million new species
* Bafa hatchery; 42.5 million bream, perch 42.5 million, 5 million new species
* Güvercinlik hatchery; million bream, sea bass, 5 million, 10 million new species
* Akarca hatchery; 37 million sea bass, turbot 1 million, 1 million flounder,
* Bafa and akarca adaptation of facilities; 195 million marine fish fry

A total of 256 million with a capacity for adaptation of fry sea farmed fish fry will be produced and Akarca Facility will be used. Kılıç Holding, a portion of the fry produced in the last three years, the amount of exports increasing from year to year. Exports from 25% in 2007, is targeted to be 40% in 2008. Exporting countries are made and work carried out; Greece, Algeria, Albania, Spain, Italy, Ukraine, Egypt and the United Arab Emirates.

8.2. Pioner company: Çamlı or Pınar

Çamlı, started modern and integrated aquaculture production in Turkey in 1985 as a pioneer in the industry. Çamlı's Fish Farming Facility is built on an area of 48.500 square meters with 12.000 square meters inland space and 36.500 square meters marine space in Ildir (Figure 12). The company has 7.000 tons of seabass-seabream, 1.000 tons of mussel and 74 million fry production capacity. The Company performs new fish species trials in order to meet continuously developing product needs of the industry. The company, set up the first off-shore cage system in Turkey. At these cages, feedings are done by the automatic camera systems, by this way; environment-friendly production has been accomplished. Çamlı implements tracebility system completely in the whole production process of the company. Çamlı aims to produce quality natural fish with affordable price for consumers. Clean environment is the key factor of producing healthy fishes.

Figure 12. Hatchery and general view of Çamlı.

Since 2006, Çamlı Fish Farming Facility certificates that its productions are appropriate for ISO 14001 Environment Management System Standards. Ecological effects of fish production areas are watched continually and reported that it's not seen any dirtiness indications. Also, Çamlı is the first company in Turkey, which is certified by Global GAP by complying the requirements of the standarts with full integration. The fresh fishes that were produced in Çamlı Fish Farming Facility were released as Turkey's first branded fish, Pınar brand and are demanded not only in domestic market but also in foreign markets like Germany, UK, Spain, Italy, UAE, Qatar, Russia, USA, and Greece. Çamlı has a mission to provide healthy and high quality seafood with competitive prices to the world market and well – nourished generations (url 2).

8.3. Mediterranean fishes culture; Akuvatur

Akuvatur 300 hectares on the sea bass and sea bream fry in 1990 and started its activities with production facilities at the Adana. Today, 5 modern integrated production facilities in different areas of R & D activities related to the cultivation of new species and only rare Mediterranean fish in the manufacturing techniques result he has managed himself, the rich assortment and "natural flavors" gives the Mediterranean kitchen again. The main activity fields "of sea bream and sea bass fry production" and "production-serve Mediterranean Fish" which Akuvat; With strong sales and distribution network in the homeland and abroad take place in the common selling point. ISO 9001, ISO 14001, Akuvatur is continuing its leading role in the industry in terms of quality with HACCP applications; "Traceability" and "sustainability" is to keep under control all processes with the implementation of environmental and product safety. Akuvatur is, with professional experts and professionals in the Mediterranean capable of producing different types at the same time in Europe remains the only company to work in the rapidly growing aquaculture sector in the world (url 3).

Figure 13. New species sea fishes and cage farms of Akuvatur.

That is how we reach 'the wild catch taste' in Akuvatur Mediterranean Fishes. Over the years it became the leader company with its unique species and fry production in Aquaculture business in Turkey, as well as in Europe. Akuvatur has an integrated aquaculture business model from fish egg to the market size product, including broodstock facility, hatcheries, feed factory, cage facility, packing facility and sales channels. Overall 200 employees, at 6 production units, a packing facility and a headquaters located at 3 different cities of Turkey (Figures 13 and 14).

Fish Fry Production, 84 million fish fry production capacity annually 20% market share. Mainly dedicated to Seabass and Seabream production for the market, Special Mediterranean fish species only dedicated to Akuvatur’s own production (Figure 15).

Figure 14. Hatchery unit and adaptation ponds at Akuvatur.

Figure 15. Situation of the cage farm and fishes.

Mediterranean Fishes Production 2.000 tones have capacity, annually.Unique Mediterranean species production; Real Dentex, Pink Dentex, Red Seabream with the whole year availibility

8.4. Some exemples Anothers companies

8.4.1. Akvatek

The company Akvatek Aqua Culture Inc. was initially an idea conceived in Izmir Karsıyaka in 1992 (Figure 16). In 1993, the first hatchery was established in a 700 thousand square meters of indoor area in İzmir Şakran. It had 150 thousand sea bass fry at that time. This number doubled and reached 300 thousand in 1995. In 1996, the company continued to carry on business by expanding its production area into 2000 m2. The sea bass fry production reached 1 million in 1997.

A year later, in 1998, the company started to produce sea bream as well. In 2004, it launched the first closed circuit system in the Turkish Aquaculture sector. While the company operated in its premises in Sakran until the end of 2010, in 2011 it began production in the region of Çandarlı – Denizköy, whose projects and investment scheme had been completed in 2008. In 2015, the company with its 29 employees realizes by producing 7 different types of sea fish in a 8000 m2 of indoor area (url 4).

Figure 16. Hatchery units from Akvatek.

The company has been continually conducting R&D studies in order to break grounds in aquaculture fry production. Research has revealed that the current range of fish will reduce due to overfishing and sea pollution caused by domestic and industrial waste.

It is inevitable that alternative sources should be seeked in order to meet the public's need for protein. Therefore, they are aiming to diversify our existing portfolio with sea fish which lend themselves to experimental fishing that has commercial value as well.

8.4.2. İlknak-Nireus

Ilknak was established in 1996 and is one of the few integrated producers of seabass and seabream in Turkey. The company operates a modern hatchery, a pre-fattening unit, 2 fish farms and a packaging unit granted in Mordogan and Karaburun, the EU export code. Its facilities are located in Denizkoy, Dikili and 100 km north of Izmir 80 km west of Izmir. Its' main offices are in Izmir.

Ilknak also produces a variety of market size farmed fish: seabass, seabream, and meagre. Ilknak's products are well-known for their high quality, reliability of service and are available fresh year round. Ilknak & Miramar have received numerous awards for their export activity and foreign currency imports from trade, their profitability and corporate tax paying (Figure 17). As a result of new investments, the capacity of the hatchery unit has been increased to 35 million pieces juvenile as of 2015.Ilknak´s new pre-growing unit produces and markets 0,3-2,0gr juveniles. The new unit has an annual capacity of 10 million juveniles.The pre-growing unit operates since April 2014 and is located in the area of Mordogan, Karaburun, 80 km west of Izmir (url 5).

Figure 17. Cage farm and coastal plant6s of Ilknak (url 5).

Ilknak owns and operates 2 fish farms with an annual capacity of 1.950 tons for market size fish. Ilknak I, with an annual capacity of 1.000 tons, produces sea bass, sea bream and meagre. Ilknak II, with an annual capacity of 950 tons, became fully operational in 2010 and produces sea bass and sea bream.

8.4.3. Agromey

Initially, Agromey was established in 2002 to supply the need of qualified fish feed and trade animal feed raw material. In recent years, Our fish feed producing capacity has grown to 42,000 tons and Mediterranean finest native fish, Sea Bass and Sea Bream up to 11,000 tons per year (Figure 18). We are the main supplier of Metro (German) and Carrefour (France) supermarket chains in Turkey and Europe. Meyfish Farm are in the most pristine, unspoiled water of the Aegean Sea. We guarantee you the most delicious fish with a just in time service and at a great price (url 6).

The company's steady success in the sector and existence of its well-located facilities in the western coast of Turkey integrated the businesses of raw material, fish feed, and fish production. With this integration, Agromey has enabled itself to form one of the best modernly equipped facilities in fish production of Turkey and Europe.

Figure 18. Open seacage farm os agromey.

Being a major producer and a supplier with quality and competitive pricing, they serve the local market and export to the European market. We export to Italy, England, Spain, Germany, France local markets and continue to be the main supplier of Metro Group and Carrefour, German and French chain stores in Turkey. With the existence of 11.000 tons of fish in our own farms 5000 tons of fish bartered in exchange of fish feed, Agromey has become the largest fish exporter in Turkey.

8.4.4. Özsu

Ozsu is an integrated fish farming company with juvenile production, on-growing and commercial distribution of Mediterranean fish species sea bass and sea bream. Comprising one hatchery, 4 on-growing sites and one processing & whole fish packing facility (Figure 19). Ozsu Fish was established in 1995 and it still continues its activities till this time. The company emphasis on employing highly qualified scientific human resources, with experienced in both aquaculture sector and fields of administration and finance, as well as excellent workers and aquaculture technicians.

The annual farming production capacity of Sea Bream and Sea Bass is 4500-5000 tons, with the target production level in 2020 standing at 10.000 tons. We anually import between 500-1000 tons of frozen mackarel from Norway and make a wholesale and distribute in domestic market. 40 % of our total production is intended for export. By the end of 2009 the countries we export consists of U.S., Spain, Italy, Germany, Netherlands and Canada. Consisting of a total of farms with a production capacity up to 5.000 tons; one hatchery with a total capacity 40 million juveniles, packing and processing capacity of 3.000 tons per annum and with its land logistic support center; is one of the leading companies of the sector in Turkey (url 7).

Figure 19. Cage farm of Özsu.

8.4.5. Ertuğ Balıkçılık-More

AKG group entering the fish business following its participation in 2002 in Mordoğan Fishery products; has taken a big step in the fishery products by joining Ertuğ Balık Üretim A.Ş. to itself in 2004. While the production continues with a capacity of 250 tones /year at Mordoğan and 1000 tones/year at Çandarlı; these two companies. Have joined under the name Ertuğ Balık Üretim A.Ş. ; as of 31.08.2007. All the applications related to increasing the capacity to 3250 tones/year are completed and Ertuğ Balık Üretim A.Ş. targets to continue its activities with this production capacity starting from 2010 (url 8).

This company, with the processing and the packing facility completed in 2008 plans to enter into the commercial products such as fillet, gutted sea bass and sea bream, whole frozen anchovy, sardines etc. as well as the frozen products market.

More Aquaculture has today three certified aquaculture farms on the Izmir coast, one of Turkey's most productive waters along the Aegean Coast, with a capacity of 3350 tones/year. Proved to be environmentally sensitive with certification from ISO 14001 and GLOBALGAP "Environmental Management Systems", More Aquaculture sustains traceability and control by digital recording of all production stages from hatching to harvesting. More Aquaculture conducts feeding operations by automatic feeders and uses environmentally friendly extruded feeds of high-tech production.

More aquaculture has the biggest volume of seabass and seabream fillet export volume from Turkey to UK. The latest product portfolio includes marinated fillets of seabass and seabream.

8.4.6. Egemar

Egemar in 1997 with a capacity of 3.5 million fry was founded at Akbuk. Made since 2005, it gave the results of R & D activities (Figure 20). The sea bream and Sea Bass fry's next first in Turkey, meagre *(Argyrosomus Regius),* Shi drum (*Umbrina cirrosa*), Sharpsnout seabream (*Diplodus puntazzo*) and white grouper (*Ephinephelus aeneus*), realized production. When the larvae from broodstock production and shipment method applied to each step until 2015 it has reached 100 million fry capacity with new investments (url 9).

Figure 20. Egemar aquaculture (url 9).

8.4.7. Akuagroup

Akua-Group is an internationaly recognized fishery group. A bluefin tuna farming entity well known in the fishing world, as a serious buyer and supplier with 1800 ton catch and 2700 ton harvest capacity(Figure 21). The ultimate fishing group from Turkey, the country engulfed by the seas on three sides (url 10).

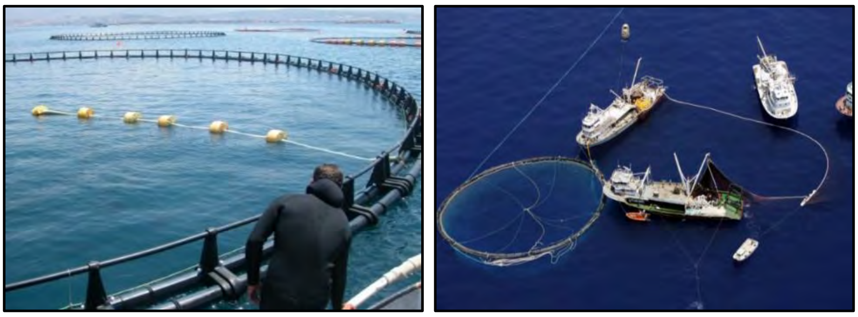

Figure 21. Some pictures Akuagroup aquaculture

8.4.8. Sagun Group

TSM was founded in order to carry out Group activities for Blue Fin Tuna Farming. It’s been continuously growing and developing since the day of its establishment (Figure 22).

Company opened its Production Plant in Antalya’s Industrial Zone in **2011**. The Production Plant was successfully inspected by Turkish Ministry of Food, Agriculture and Livestock and entitled with EU Approval Number. Now different kind of agricultural and wild caught seafood products are processed and exported from this Plant (url 11).

Figure 22. Sagun Group aquaculture

9. Results and Discussion

Our country meets all the needs of our country in the aquaculture system as it has become the leader in the region. Which should apply in the marine business according to the system of off-shore and inland waters in the reservoir as well as advanced and modern technology has made great strides in aquaculture. The cage structure as materials are exceeded world standards, the production capacity the increase is provided in the cage, depending on size (TÜGEM/SÜDB,2004).

Therefore, aquaculture and natural systems could increase knowledge about the interactions between programs and technologies to reduce the effects, it should be supported.

Special fish of the Aegean Sea, as well as almost every part of our country through farm was consumed at very reasonable prices, it has helped establish another benefit of the fishing ban on the supply and demand balance. In addition, the Aegean Sea, such as recreation and culture sensitive areas / tourism industry, local communities, other areas and water supply state to prevent conflicts between users such as fisheries and environmental protection, is obliged to fulfill its responsibility by encouraging the development of alternative technologies and the allocation of a rational source.

The privite sector responsibilities; cultivation of which is a private sector initiative and commercial development to be able to compete in the primary sectors of the domestic and foreign markets with the knowledge that it is responsible for creating a dynamic sector, the state's help policy regarding the use of sustainable resources, R & D efforts and provide support to the resolution of problems, especially the least developed region to contribute in the socio-economic development, sustainable development is the existence of the sector and sensitivity to the consumer and the environment as primary borrower.

• produced and reared fish are all used the natural environment, sea bass and sea bream are native species of the Mediterranean. That does not upset the natural balance of escape from the farm. Production of species not found in the waters of Turkey to the very nature-even if the chances of reproductive Republic Ministry of Agriculture does not permit anyway

.• A large part of the grown fish are exported to Europe, so the food in Turkey, even though the drug and chemical control are not enough, the products are inspected by the standards of the European Union. The fish consumed in Turkey, does not come from countries where there is no control.

• Broodstocks produced in natural stocks used for fish, sea bass and sea bream fish because as broodstocks be stored and used as a source of eggs for years.

• With the aim to minimize the drug use, the fish are vaccinated against the disease have been recorded and are used drugs that are demanded by customers in the European Union

.• Most of the raw materials consumed and feed under the supervision of the European Union

.• It is under the protection of aquatic mammals found in most production regions.

• From 2004 to this day are transported in the appropriate fields. For the remaining farms, there is no place to move after such notification.

• All the fish farms are licensed and including the Ministry of Forestry and Environment were established with permission from nine ministries.

Since 2008, the Turkish aquaculture sector is experiencing a period of consolidation creates occurs through large-scale company acquisitions and merger. On-site having hatchery, feed mill, farms, product packaging and processing plant the number of groups with which vertical integration is growing from year to year.

Turkish Aquaculture sector, the current and most advanced standard of food "GlobalGAP" HACCP, BRC and IFS systems commonly use. In this way, production can be observed in each stage and the analysis are both the current situation can be monitored retrospectively. State and sector periodically audited by the EU authorities to demonstrate full compliance with the continuity of the quality process. (Anonym, 2009).

The rapidly growing aquaculture industry in Turkey is pushing to export naturally higher. The consumption of high quality and safe seafood from the market ensures continuous development of commercial motivation request product range and quality. Currently Turkey seafood is exported to 80 countries worldwide. Starting with 3000 tons of production in 1986 reached 212.5 thousand tons in 2014 of this sector. Modern technologies used in R & D activities, in terms of investment attractiveness and employment size Aqua culture industry is one of the shining stars of the economy.

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BACTERIOLOGY OF THE AEGEAN SEA

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1. Introduction

The Aegean Sea is a part of Mediterranean Sea. It is a semi-closed sea surrounded by Turkey and Greece and it is a sub area of the Mediterranean Sea. Its most important geographical peculiarity is the presence of numerous islands and islets (Zaitsev and Öztürk, 2001). Ever since a detailed study of the bacteriology of the Aegean Sea began at the end of the nineteenth century. Continuing new discoveries in marine microbiology necessitate radical rethinking of our understanding of sea processes. We now realize the vital role that marine microbes play in the maintenance of our planet, a fact that will have great bearing on our ability to respond to problems such as the increase in human population, overexploitation of fisheries, climate change, and marine pollution. Study of the interactions of marine bacteriology with other organisms is providing intriguing insights into the phenomena of food webs, symbiosis, and pathogenicity. Since some marine microbes produce disease or damage, we need to study these processes and develop ways to overcome them. Finally, marine microbes have beneficial properties such as the manufacture of new products and development of new processes in the growing field of marine biotechnology. This chapter sets the scene for the summarizes of bacteriology studies conducted in the Aegean Sea.

1.1. Microbial Pollution

The pelagic zones of the northern Aegean Sea and the Sea of Marmara share some main features due to their connection through the Çanakkale Strait. However, because of the anthropological sources, bacterial pollution level of northern part of the Aegean Sea less than the Sea of Marmara (Altuğ *et al*., 2007) (Fig 3). The population rate rises during the summer season due to recreational activities, compared with the other months in the coastal areas of the Aegean Sea. This situation is inducing the level of bacterial pollution (Altuğ *et al*., 2007).

Microbial contamination in surface waters of coastal areas is a problem affecting recreational and commercial uses of bays, estuaries, and rivers (Gersberg *et al*., 1995). Excessive increases in human activities, urbanization, and industrialization have disturbed the balance of the coastal environment. Fecal contamination of seawater and beaches poses a serious threat to public health because fecal wastes include bacteria, viruses and protozoa cause intestinal infections if taken through the digestive system. In particular, well-known pathogenic bacteria such as *Escherichia coli, Salmonella, Shigella, Campylobacter, Vibrio,* and *Yersinia* protozoa such as *Cryptosporidium* and *Giardia*, and viruses such as norovirus and adenovirus are the main factors associated with recreational water-borne diseases. Therefore, instead of identifying them individually, it is preferred to investigate the presence of indicator organisms, because their identification is faster and more economical. These indicator bacteria are Total coliforms, Fecal coliforms, *E. coli* and Enterococci, and they have been investigated as indicators of contamination for about 100 years (Schwab, 2007; Kacar, 2011a; Altug *et al*., 2013).

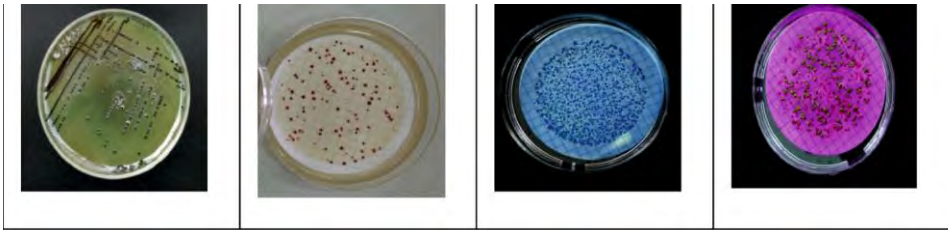

Figure 1. *Salmonella* sp., fecal streptococci, total coliform, fecal coliform

A study, it was investigated the percentage distribution of the values for the ratio of fecal coliform to fecal streptococci in the surface water of the Aegean Sea. The contribution of fecal coliform bacteria to fecal streptococci (FC/FS > 0.7) showed that the sources of fecal contamination were anthropological in Aegean Sea in 2006- 2008. Seven of the 22 unit seawater samples were found positive for *Salmonella* spp. in the sea water samples which were taken from the coastal areas of the Aegean Sea, Salmonella spp. positive samples were positive correlated with the indicator bacteria count. Positive correlations were observed between the level of indicator bacteria and the presence of Salmonella, implying that *Salmonella* spp. occurrence is a part of anthropological pollution input in the investigated areas. The presence of isolates of *Salmonella* spp. in the marine environment is the occurrence of Salmonella in various marine environments in Turkey 87 of notable significance with respect to public health due to the potential risk of acquiring infections as a result of the consumption of contaminated aquatic products or ingestion of contaminated seawater (Altuğ *et al*., 2007).

Kacar (2011a) reported the bacterial indicators of fecal pollution (fecal coliforms and fecal streptococci) in the five rivers (Meriç, Gediz, Bakirçay, Küçük Menderes, and Büyük Menderes), which show their impacts in the Aegean Sea they flow into. Water quality was monitored in the five rivers (Aegean Sea) to provide a useful protocol for assessing diffuse pollution impact on the river quality. The highest fecal coliform result was obtained in winters (1.3×10^6 cfu/100 ml) while maximum fecal streptococci value was detected in autumns (6.3×10^4 cfu/100 ml) in the Küçük Menderes River during 2006–2008. The Küçük Menderes River is the biggest pollution source, and carries the maximum amount of fecal coliforms and fecal streptococci to the Aegean Sea. Considering the findings of these studies, it can be said that there is fecal pollution in the rivers reaching the Aegean Sea. The results show that there are a great number of microbial pollution sources in the areas where the river passes through and thus, in order to implement strategies to improve water quality in these rivers, monitoring of these rivers should continue.

In a similar study conducted in the northern rivers of Greece, the river quality was found normal; however, due to the agricultural activities, the area is under risk. Maximum fecal coliform and fecal streptococci values were determined as 1×10^3 cfu/100 ml (Karanis *et al*., 2005). The high number of fecal coliform bacteria in a river suggests that there exists severe contamination in that river. The agricultural activity may have affected the magnitude of the concentration. Effects of land-use on diffuse pollution were reported by many researchers (Isobe *et al*., 2004; Karanis *et al*., 2005).

İzmir is located on the Eastern Coast of the Aegean Sea and it is one of the biggest bays in the Mediterranean Sea with totally 500 km2 areas and 11.5 billion m3 water capacityv. Among the main sources polluting İzmir Bay are domestic and industrial wastes, effluents from marine vessels, and polluted waters carried by rivers and streams.

In a study was conducted in İzmir Bay by Kacar and Gungor (2010). The aim of the the study was to assess the density of fecal coliforms and to evaluate the changes in the marine environment after installation of a treatment plant in the bay. Maximum surface fecal coliform concentration was found 4.9×10^5 cfu/ 100 ml in 1996–2000 periods. Following the opening treatment system, fecal coliform density decreased 2.1×10^4 cfu/100ml during 2001–2005. A continuous improvement can be sustained in the water quality if direct inflow of untreated wastewater is prevented. The fecal coliform levels decreased in 5 years. Nevertheless, there are still some problems to solve, such as direct inflow of streams and their runoff material including several uncontrolled domestic and industrial discharges. A continuous improvement can be sustained in the water quality if direct inflow of untreated wastewater is prevented. In previous study, Kocasoy *et al*. (2008) investigated sea water quality at selected two beaches and a coastal village having summer resorts in Çeşme (İzmir) and found that the maximum total coliform value had been reduced from $10x10^4$ to $9.2x10^1$ cfu/100ml after wastewater treatment plant. Fecal contamination in seawater of the beaches can stem from many point and non-point sources (Kacar and Kucuksezgin, 2014). Therefore, all the beaches should be carefully monitored as much as possible both in terms of public health and in terms of their impact on the environment.

In another study, fecal coliform densities were determined to evaluate the degree of water pollution and *Tapes decussatus* (from Izmir Bay) microbiological accumulation of the classical microbial pollution indicators. Throughout the study period, concentration of heterotrophic bacteria and fecal coliform varied between 1.2×10^5–6.8×10^5 cfu/100 g and 3.3×10^3–2.4×10^5 mpn/100 g in clams, respectively. Maximum heterotrophic bacteria and fecal coliforms were recorded in the winter while the lowest were detected in summer (Kucuksezgin *et al.*, 2010).

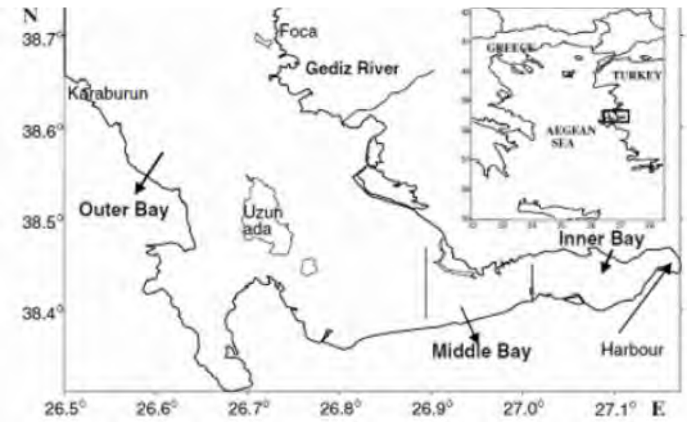

Figure 2. İzmir Bay (Kucuksezgin *et al.*, 2010)

The other study on the *Mytilus galloprovincialis* harvested from İzmir coastal area, some microbial characteristics were determined in samples (Kacar, 2011b). The mean number of culturable heterotrophic bacteria varied between 1.7×10^5–6.7×10^6 cfu/100 g in *M. galloprovincialis*. Levels of fecal coliform were determined to be higher than the allowed limit (300 mpn/100 g) in all the stations during the study period. The concentration of fecal coliform in the highest value was 2.4×10^5 mpn/100 g and the lowest one was 2.3×103 mpn/100 g. In the present study, the presence of *Salmonella spp*. was positive in one or more stations. Shellfish contamination from sewage polluted waters is a serious and continuous problem: *Salmonella* spp. has been shown to survive for over a month in the aqueous-sediment microcosm (Fish and Pettibone, 1995), and is also frequently isolated from coastal waters and shellfish (Yilmaz *et al.*, 2005). This situation is very important for public health so we believe that raw shellfish should not consume to prevent the foodborne diseases.

Working with the same shellfish species, Soultos *et al*. (2014) reported that one hundred and two samples of mussels (*Mytilus galloprovincialis*), harvested from approved shellfish coastal water in northern Greece, were screened for the presence and antimicrobial resistance of *Listeria monocytogenes* (pathogenic bacteria) derived from polluted aquatic environments. The isolate identified as *L. monocytogenes* was defined as serogroup I and found to be resistant to nalidixic acid and streptomycin. *Listeria monocytogenes* is widely distributed in the environment and has been isolated from numerous sources, including the intestines of humans, domesticated animals, and birds and many foods and environmental samples. The presence of *L. monocytogenes* serogroup I in the study was of public health concern, because of the possibility of causing human listeriosis.

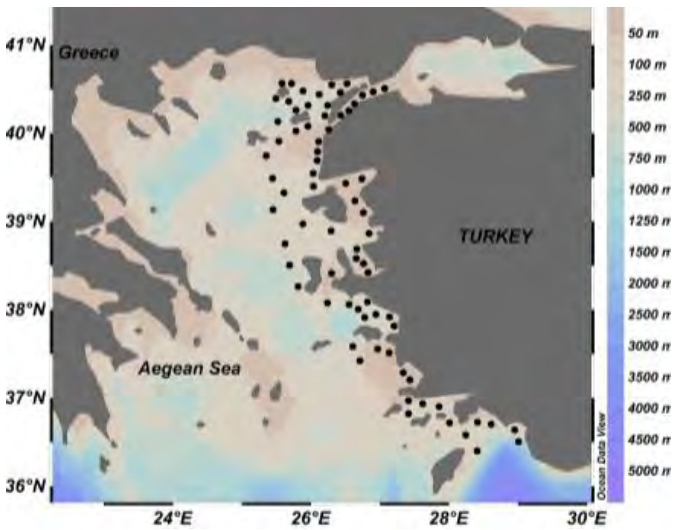

Figure 3. Study Area: North Aegean Sea, Gökceada and Thasos Island, the offshore and coastal areas of the Aegean Sea, Güllük Harbor, İzmir Bay

Güllük Harbor (Aegean Sea, Turkey) is one of the important potential pollution sources among various factors such as recreational, domestic and industrial activities. In a study, bio-indicator bacteria and environmental variable parameters were investigated in the coastal areas of the Güllük Bay, Aegean Sea (Kalkan and Altug, 2015). The seawater samples which were taken from surface (0–30 cm) were tested regarding total and fecal coliform, streptococci from May to February in 2012–2013. The highest fecal pollution stress and indicator bacteria values were observed in the period between June and August. The levels of total coliform were ranged between $3x10^1$ cfu/100 ml and $2.164x10^6$ cfu/100 ml. The levels of fecal coliform were ranged between 0.1x101 cfu/100 ml and $1.46x10^4$ cfu/100 ml. The levels of fecal streptococci were ranged between $0.1x10^1$ cfu/100 ml and $2.11x10^4$ cfu/100 ml. The highest heterotrophic aerobic bacteria count was found in the surface water samples. The levels of total organic carbon (TOC) were recorded to be maximum 4.73 % in the sediment samples. The highest percentage of bacterial metabolic activity in the sediment and sea water samples was recorded to be in 90 %, 60%, respectively in the summer period. The finding showed that bacterial pollution sources of the study area, especially in the summer season, under the control of increasing anthropogenic activities. The finding showed that terrestrial pollution sources carry a potential risk for public and ecosystem health and the sustainable use of living sources. Precautions should be formulated and put into action immediately in order to protect the region from bacteriological risks (Altuğ *et al*, 2013, Gürün *et al*. 2013) (Figure 3).

Heterotrophic bacteria play a key role in marine biogeochemical cycling and food-webs because of the wide diversity of their metabolic properties. Although culture independent studies have served as common applications in detecting bacterial diversity, there are also a number of studies in which it has been shown that cultured strains of marine bacteria can represent significant fractions of the bacterial biomass in seawater (Rehnstam *et al*., 1993; Pinhassi *et al*., 1997). There is still no knowledge about culturable heterotrophic bacteria diversity in the Aegean Sea of Turkey. *Escherichia coli* have previously been reported from the northern Aegean Sea (Altug and Erk, 2001). The presence of twenty-five bacteria species belonging to ten different families from the southern part of the Sea of Marmara and the northern Aegean Sea were reported for the first time. While the bacteria species belonging to the Gamma-Proteobacteria class were found to be the highest. Among all the strains, percentages of the Gram (-) bacteria in the northern part of the Aegean Sea were 46 %. On the other hand, the common taxonomic group in the Aegean Sea was found to be Bacilli (47%), followed by Actinobacteria (28%), and Gamma-Proteobacteria (25%) (Altug *et al.*, 2012). *Shewanella putrefaciens* was abundant in the northern Aegean Sea. *Staphylococcus hominis* was reported as a less-common species in clinical specimens but, on the contrary, it was dominant in water samples collected from unpolluted regions (Gunn *et al*., 1983). A study, *S. hominis* was dominant in water samples collected from the northern Aegean Sea. The differences of bacterial taxonomic composition may be strongly related to unpolluted conditions of the northern Aegean Sea (Altug *et al*., 2007). During the study period (2006-2007), a total of 27 taxa of aerobic heterotrophic mesophilic bacteria including 10 bacterial classes were reported for the first time from both seas. Also, the percentages of metabolically active bacteria were compared for the first time in the sea water samples which were taken from northern part of the Aegean Sea, Turkey. According to the sampling area, bacterial activity level was recorded higher in the samples that were taken from the surface than other samples that were taken deeper.

Altug *et al*. (2010), mesophilic heterotrophic aerobic bacteria number were found to be between 5.4–7.1 log10 cfu/100 ml at 18 stations, during August 2007, in the

Aegean offshore area. During the study period, six bacterial classes: Gamma Proteobacteria (58%), Beta Proteobacteria (%11), Alfa Proteobacteria (5%), Flavobacteria (12%), Actinobacteria (6%) and Bacilli (5%) were determined. Gamma Proteobacteria was the most common group in terms of species number in comparison to the other taxonomic groups in the coastal areas. The aerobic heterotrophic culturable bacteria species from Aegean Sea, Turkey is listed in Table 1. (Altuğ *et al*., 2010; 2012; 2013, Çardak *et al*., 2013).

Another study, it was reported, the highest hetetrophic aerobic bacteria abundance was found in the coastal stations. This situation was evaluated to be a result of anthropological pollution input in the coastal areas. Species belonging to *Enterobacteriaceae* family was the most common taxonomic group in the Northern Aegean Sea. *Flavobacteriaceae* family was the second most common group. Among all the strains, percentage of the Gram negative bacteria in the coastal areas and the offshore area were 90% and 2%, respectively. This situation suggests that those particular species have potential importance in organic matter turnover in these areas. Although these bacteria had not previously been reported from these areas, they may be ubiquitous in aquatic environments. The bacteria which were isolated from various marine environments have shown different compositions.

Similarly, study, it was to investigate total and culturable heterotrophic bacteria levels at the sea water samples taken from 19 stations determined around Gökçeada Island, Northern Aegean Sea. The highest total and culturable heterotrophic bacteria level was recorded at Cape of Kömür in summer sampling survey (Çiftçi Türetgen and Altuğ 2015. During the study period, eight bacterial classes: Bacilli 48% 48, Alpha Proteobacteria, 24%, Gamma Proteobacteria 17%, Beta Proteobacteria 8% , Actinobacteria, 1% Lactobacillales 1%, Sphingobacteria %1 and Cocci 1% were determined. Totally, twenty-four bacteria species Gökçeada Island, Northern Aegean Sea were reported for the first time. The highest frequency of occurrence in the island *Sphingomonas paucimobilis* (20.6%) was determined.

Therefore, it is important to monitor microbial pollution indicators in the coastal areas located close to urban areas, agricultural lands and river inputs; in other words, point and/or non-point sources of pollution. Monitoring regularly of bacterial water quality on coastal areas is necessary to understand anthropogenic impact of pollution sources. Predictions and preventions against pathogens and related water-borne disease may improve more efficiently for public and ecosystem health and the sustainable use of living sources.

Table 1. Aerobic heterotrophic culturable bacteria species from the northern Aegean Sea, Turkey.

Isolated bacteria	
Acinetobacter lwoffii, Audureau 1940	*Myroides spp.* Vancanneyt *et al.* 1996
Aeromonas caviae Eddy1962	*Neisserie animaloris* Berger 1960
Aeromonas hydrophila Chester, 1901	*Pasteurella canis* Mutters *et al.* 1985
Aeromonas salmonicida Lehmann and Neumann 1896	*Pediococcus pentosaceus* Mees 1934
Aeromonas sobria Popoff and Véron 1981	*Pseudomonas aeruginosa* Schroeter 1872
Alicyclobacillus acidoterrestris Deinhard *et al.* 1988	*Pseudomonas luteola* (Kodama *et al.* 1985) Holmes et al. 1987
Bacillus pumilus Meyer and Gottheil 1901	*Pseudomonas oryzihabitans* Kodama *et al.* 1985
Bacillus vallismortis Roberts *et al.* 1996	*Salmonella enterica* Kauffmann and Edwards 1952
Brevundimonas diminuta Leifson and Hugh 1954	*Serratia liquefaciens* (Grimes and Hennerty 1931) Bascomb *et al.* 1971
B. vesicularis Büsing *et al.* 1953	*Serratia fonticola* Bizio 1823
Burkholderia cepacia Palleroni and Holmes 1981	*Serratia marcescens* Bizio 1823
Chryseobacterium indologenes Yabuuchi *et al.*1983	*Serratia odorifera* Grimont *et al.* 1978
Cedecea davisae Grimont *et al.* 1981	*Shewanella algea* Simidu *et al.* 1990
Citrobacter freundii Werkman & Gillen, 1932	*S. putrefaciens* Lee *et al.* 1981
Dermacoccus nishinomiyaensis Oda 1935	*Sphingomonas paucimobilis* Holmes *et al.* 1977
Enterobacter aerogenes Hormaeche and Edwards 1960	*S. thalpophilum* Holmes *et al.* 1983
Enterobacter cloacae Jordan 1890	*Staphlococcus lentus*Schlifer *et al.*1983
Enterobacter sakazaki (Farmer *et al.*, 1980)	*Staphylococcus epidermis* (Winslow & Winslow 1908) Evans 1916
Enterococcus faecalis (Andrewes and Horder 1906) Schleifer and Kilpper-Balz 1984	*Staphylococcus hominis* Kloos and Schleifer 1975 emend. Kloos *et al.* 1998
Escherichia coli T. Escherich, 1885	*Staphylococcus intermedius* Hajek 1976
Klebsiella pneumoniae ssp. pneumoniae Schroeter 1886	*Stenotrophomonas maltophilia* Hugh 1981
Kocuria kristinae Kloos *et al.* 1974	*Vibrio alginolyticus* Miyamoto *et al.* 1961
K.varians Migula 1900	*V.parahaemolyticus* Fujino *et al.* 1951
Lactococcus lactis ssp *lactis* (Lister 1873) Schleifer *et al.* 1986	*V. vulnificus* Reichelt *et al.* 1979
Micrococcus luteus Lehmann and Neumann 1896	

2. Heavy Metal and Antibiotic Resistant Bacteria

Heavy metals in industrial wastes and some pesticides may become a threat to the ecological balance. Additionally, ship dismantling activities lead to many problems such as the discharge of detrimental and persistent pollutants affecting the coastal zone where dismantling is conducted, deep sea water and sediment. Entrance of metals to aquatic environments may occur by natural or human resources. Presence of these heavy metals in the marine environment may pose a serious threat to the environment because of their ability to persist for several decades (Kamala-Kannan and Lee, 2008; Altuğ and Balkıs, 2009).

Although microorganisms are sensitive to various concentrations of heavy metals, they have mechanisms which enable them to proliferate in the environment by rapidly adapting to that environment and to convert heavy metals into harmless forms through biosorption or enzymatic transformation. Microorganisms develop various mechanisms in order to tolerate the metals. These mechanisms include converting into volatile form, extracellular precipitation, adsorbing cell surface, and intercellular accumulation. Also, bacteria perform chemical transformations of these metals. Heavy metal resistant microorganisms may be used in genetic transfer studies of the heavy metal resistance mechanism (De Rore *et al*., 1994; Çardak and Altuğ, 2014). Thus, individual bacterial strains will develop their capacity to survive under toxicological stress and will be of importance in future bioremediation strategies. However, correlation is frequently observed in antibiotic resistance besides metal resistance because resistance genes in chromosome or plasmid are close to each other. Increases in antibiotic resistance lead to problems in the treatment of infectious diseases worldwide. Therefore, it is needed to be careful when pesticides, antimicrobials containing metals and antibiotics entering the environment are used (Kamala-Kannan and Lee, 2008; Li and Ramakrishna, 2011; Kacar and Kocyigit, 2013)

In a study, it was indicated bacteriological pollution indicators in Çanakkale Strait, Northern Aegean Sea and to determine the level of resistance to beta-lactam antibiotics of isolated from bacteria. The highest level of indicator microorganisms found in centre of Çanakkale, Kepez and Dardanos stations. It was found that the isolates showed elevated resistance to kanamycin, vancomycin and ampicillin (Çardak and Gencer, 2010).

Another study, Altuğ (2005) was found that the highest antibiotic resistance cefuroxime and ampicillin from isolated bacteria to Oludeniz Lagun, Aegean Sea. It was reported; antibiotic resistance level which determined highly in coastal areas was showed that area was affected by land resources pollution. The level of fecal bacteria which were determined highly in summer period was associated with insufficiencies of purification systems and icrease of population on seasonally.

In a study, Kacar and Kocyigit (2013) examined isolation and identification of sediment bacteria from the ship dismantling area in Aliağa and these sediment bacteria were investigated in respect of the minimum inhibitory concentrations (MICs) of heavy metals and susceptibility of some antibiotics (ampicillin, tetracycline, chloramphenicol, vancomycin, gentamicin and tobramycin). Thirteen bacterial isolates were obtained from sediments and phylogenetic analysis using 16S rDNA indicated that the 13 strains belong to genus *Bacillus* was submitted to GenBank (JQ030907-JQ030919). The MICs of heavy metals were different for each strain but the general order of resistance to the metals was found to be as Pb>As>Ni>Co>Cu>Zn>Cr>Cd>Hg and the toxic effects of these metals increased with increasing concentration. Additionally, it was found that the strains were resistant to gentamicin followed by tobramicin.

In a study by Kacar *et al*. 2013 in İzmir Bay, heavy metal resistant bacteria collected from the harbor and other areas of İzmir Bay sediments were investigated. Twenty-six isolates were identified and these strains were investigated in respect of the MIC of metals, susceptibility of some antibiotics (ampicillin, tetracycline, chloramphenicol, tobramycin). Phylogenetic analysis using 16S rDNA indicated that the 26 sediment strains belong to genus *Bacillus, Halobacillus* and *Marinibacillus* were submitted to GenBank and assigned the accession numbers KJ161398-KJ161424. The MICs of metals were different for each strain but the general order of resistance to the metals was found to be as Ni>Pb>Cu>Cr>Cd>Hg and the toxic effects of these metals increased with increasing concentration. It was determined that the most toxic metal for bacteria was Hg. In this study, it was observed that the highest resistance was to Ampicillin as in most of the studies considering heavy metal and antibiotic resistance mechanisms are similar. These results showed that the identified bacteria are able to survive in sediments polluted by heavy metals. The identification of species with poly-resistance to especially heavy metals and antibiotics may indicate that these coastal areas may have problems, which may pose a risk for humans and animals. Therefore, the isolates may be useful as indicators of potential toxicity of heavy metals in coastal area to other forms of life and they could be designed as bioremediation tools by advanced studies.

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HARMFUL ALGAL BLOOMS (HABs) AND AEGEAN SEA

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1. Introduction

Over the last few decades, there has been a clear trend towards increased population density in coastal areas which involves highly developed landscapes and major exploitation of the coastline for commercial and recreational purposes (UNEP 2006). As one of the most exploited parts of Mediterranean Sea for ancient times, Aegean Sea is a typical example site exhibiting this trend. Since the ancient times, the Aegean coasts are functional and attractive habitats for populated human settlements, due mainly for sea related economic sectors such as maritime transportation, fishing and tourism with related recreational activities. The most prominent pressures are: 1) maritime transportation, in particular those vessels transiting forward and backward to/from Black Sea and Sea of Marmara, and 2) human occupation of coastal zones for tourism, secondary housing, and recreational activities. The first is reflected in data records of a recent study on the risk posed by shipping in the Aegean Sea (Shepperson *et al.,* 2012), as over 35,000 vessels per year traversing through the main route, or alternatively about 100 large vessels every day. The second has showed an exponentially increasing trend with rapid developments in small rural sites, which have been converted to municipalities without sufficient infrastructure and well-designed development plans. Considering the facts that there are 800,000 yachts sailing in the Mediterranean with an annual increment rate of 50,000-60,000 yachts per year, and Aegean Sea is one of the most popular sailing sites, the pressure caused by yachting can quantitatively be imagined.

Inevitably, such intensification along the coastal areas has faced a series of environmental pressures on the coastal marine ecosystems. Harmful Algal Blooms (HABs) are actually an apparent response of the marine ecosystems to these environmental pressures, particularly those related with the anthropogenic eutrophication. Nevertheless, there are also some natural mechanisms that may trigger HABs, for instance, climate changes which can also create conditions such as severe floods that carry vast volume of organic material to coastal marine environment within hours or days.

HABs that are caused by anthropogenic impacts particularly fits to the definition of ecological response since it creates consequences related with the health human being and ecosystems itself. HABs may cause harm through the production of toxins or by their accumulated biomass, which can affect co-occurring organisms at varying trophic levels and alter food-web dynamics. Impacts include human and mortality following consumption of seafood or indirect exposure to HAB toxins, substantial economic losses to coastal communities and commercial fisheries, and HAB-associated fish, bird and mammal mortalities.

These consequences have depreciating influences on several socio-economical activities of societies, such as fisheries, aquaculture, and tourism. As parallel to the global trend, the frequency of occurrences of HABs incidents has gradually increasing in the Mediterranean which is the largest semi-enclosed basin (Figure 1). The very first record on HABs incidents was from Aegean Sea. Numann (1955) reported as a red-tide incident from Izmir Bay (Koray, 1983). Since then, the observation and studies clearly reveals the increasing trend.

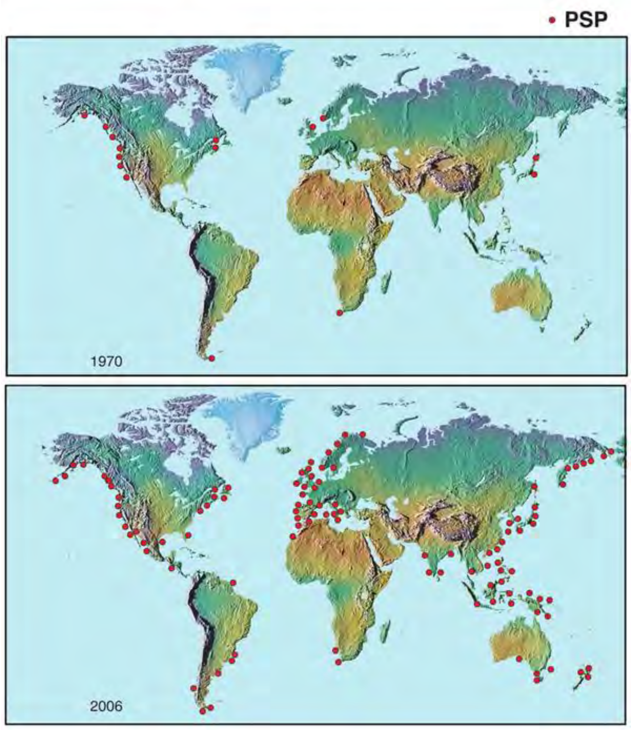

Figure 1. The comparison of the number of HABs incidents producing PSP toxin in 1970 and 2006 (https://www.whoi.edu/redtide/regions/world-distribution).

Among 4000 microalgae, only 200 species are potentially nuisance or harmful and only 90 out of 200 species, mostly dinoflagellates (Dinophyceae), are known as toxin producers (Hallegraeff *et al.* 2003). Nevertheless, there are also diatoms (Bacillariophyceae), silicoflagellates (Dictyochophyceae), raphidophytes (Raphidophyceae) ve prymnesiophytes (Prymnesiophyceae),

2. On the Mechanism of HABs formation

A snapshot from the summary on the topic of this section which is available at (https://www.whoi.edu/redtide/home), provides a perfect beginning.
"*Marine waters, fresh waters as well, teem with life. Much of it is microscopic and they are mostly harmless. In fact, all aquatic life ultimately depends on this microscopic life for food. Most of these species are harmless phytoplankton and cyanobacteria; however, there are a few dozens that are able create potent toxins when the right conditions prevail.*"

The question is "What are the right conditions". This question has been challenged for years and the ultimate answer is yet not available, however there are substantial progresses with an accelerating pace. Today, the most important identified factors on the formation of bloom dynamics are physical rather than chemical and/or biological, *i.e.,* stratification of water column and the degree of replenishment of water mass. It is obvious that these physical conditions determine the degree of influence of biotic and abiotic ecological factors of the spatial unit in which bloom may be formed. A pre-conditioning is required. This means that the physical (coastal geomorphology, hydrodynamic properties such as prevailing currents regime, degree of stratification/vertical mixing, presence of convergent gyres, light, salinity and temperature, *etc*), chemical (nutrient concentrations, anthropogenic loads, *etc*) and biologic (species composition, the occurrence of toxic species, species-specific growth rates, production of a species-specific allelopathic substances, cyst forming ability, *etc*) processes has to be synchronously adjusted for boosting reproduction of a single, or sometime a small group of species. When the physical dynamics of water masses forms a pattern in which the transported particles, *i.e.,* phytoplankton, bacterioplankton, have been aggregated in a given area, their abundance can exceed the limits of growth rate by several folds. Thus they can change the water color and the blooms become visible. In fact, this is always not the case because some species do not change the water color. Thus, the actual frequency of HABs incidents cannot be determined only by visual observation. Another fact makes HABs incidents difficult to observe is high variability of the duration of HAB formations which may range from days to months. The size of the patchy formation of HABs is also highly variable. It may range from some 100 meters to several kilometers.

3. HABs in Aegean Sea

Based on current knowledge, HABs in the Mediterranean Sea usually occur in near shore coastal areas and in some specific "hot spots". The Alboran Sea, the Ligurian-Provençal Basin, the Adriatic Sea, and the Northern Aegean Sea are the record rich areas (Moncheva *et al*., 2001; Ignatiades and Gotsis-Skretas, 2010). Some hotspots in Aegean Sea are Thermaikos and Kavalas Bays in the North Aegean Sea, Pagassitikos, Malliakos, Evoikos and Saronikos in the Western Aegean Sea, Messiniakos Bay in the Southern Aegean Sea, Amvrakikos in the Ionian Sea and the Kalloni Bay of Mytilini Island, Izmir Bay and Gulluk Bay in Eastern Aegean Sea. In these sites, the levels and availability of nutrients, phytoplankton abundance and harmful algal species are much higher than they are in open waters (Ignatiades and Gotsis-Skretas, 2010).

Table 1 summarizes the potentially harmful, *i.e.,* toxic and/or nuisance, species on the basis of their functionalities, as well as their causatives when possible. The term "*causative*" here refers the toxicities, toxins and/or their effects together with relevant references when available. The toxicities observed in the Aegean Sea are Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP), The well-known toxins are Saxitoxin (PSP), Yessotoxin (also coded as YTX) and Okadaic acid (DSP), Ichthyotoxin (fish killers), Domoic acid (ASP). However, there are also a derivative of these toxins usually which are named after the species producing them, such as Dynophysistoxin and Palytoxin. There are also some non-toxic but potentially harmful species. They are usually efficient bloom formers which can reach extreme level of abundances and they can clog the gills of fishes or when they dies, an excessive organic matter input can deplete the oxygen in the surrounding environment. The bloom formers have also been noted in the Table 1 for emphasizing that all harmful algae do not necessarily reach to high abundance.

Since 1987, when paralytic and diarrhetic shellfish poisoning (PSP and DSP) contaminations were described for the first time in the Mediterranean Sea (Delgado *et al*., 1990, Belin, 1993), toxic events have been reported from different coastal areas of the entire Mediterranean basin. The most widespread species in the Mediterranean basin over the last few decades was a PSP producer *Alexandrium minutum* which had also been observed in Izmir Bay (Koray and Büyükışık, 1988). PSP includes causative species within the genus Gymnodinium. *G. catenatum* is a naked chain and resting cyst forming dinoflagellate. Numerous studies in recent decades reveal a worldwide distribution of this species and there is an apparent increase in the detection of this species in Mediterranean Sea. *G. catenatum* was identified in nutrient –rich Izmir Bay as the causative species of an important PSP event. The toxic species in the genus Dinophysis can cause DSP episodes despite their cellular concentrations are very low, *i.e.,* 102 –104 cell l^{-1} (Reguera *et al.,* 1990; Blanco *et al.,* 1995). This genus is widespread throughout the Aegean Sea, particularly Izmir and Gulluk Bay. Other dinoflagellates producing diarrhetic toxins are the genus Prorocentrum; particularly *P. micans*, *P. triestinum* and a benthic species *P. lima*. The genus Pseudo-nitzschia, as a pennate diatom, is responsible for ASP events worldwide, through the production of a neurotoxin, Domoic acid (Bates *et al.,* 1989). The species distribution of this genus is quite wide in Aegean Sea. Domoic acid has been reported in bivalve mollusks from French and Greek coasts (Azmil *et al.,* 2001; Kaniou-Grigoriadou *et al.,* 2005). Two species producing Yessotoxin (YTX), a brevetoxin-type polyether, have also been detected along the Aegean Sea which is produced by *Protoceratium reticulatum* and *Lingulodinium polyedrum*. Harmful effects on humans also include an uncommon genus, Ostreopsis, which are benthic or epiphytic dinoflagellates and two toxic Ostreopsis species produce palytoxin-like toxins, one of them, *O. ovate*, have recently been identified in the Aegean Sea (Bizsel and Aligizaki, 2011). Since 1998, the genus has been associated with inhalation exposure to marine aerosols containing toxins that cause respiratory symptoms, fever, and skin irritations in humans. Another species that may cause fauna mortality, in particular heavily eutrophicated sites are found within the group of Raphidophytes: *Heterosigma akashiwo*, which reported from Izmir Bay (Bizsel and Bizsel, 2001) and Halic Estuary (Golden Horn) (Tas and Yılmaz, 2015).

Apart from their harmful effects on human and environmental health, the economical consequences of these incidents are also remarkable and require much closer attention. Recurrent blooms, with substantial economic losses, have been described in various harbors, bays, and shellfish farms located throughout the basin (Ignatiades, *et al.*, 2007; Van Lenning *et al.*, 2007). As an example of the potential magnitude of economic losses, overall costs in Australia have been estimated between $150-200 million in U.S. 2002 dollars (http://www.whoi.edu/redtide/page.do?pid =15315). Same reference also states that these impacts have unfortunately not been well quantified and documented in the U.S. However, some published reports have been revealing that the Coastal HAB events have been estimated to result in economic impacts in the U.S. of at least $82 million each year (http://www.oceanservice.noaa.gov/hazards/hab/).

A list of HABs species observed in Aegean Sea, nuisance or toxic, has been given in Table 1. As shown in the table, there are 45 bloom former species, 20 toxic species and 4 species which are both bloom former and toxic. In addition, there are also 5 species which are likely to be bloom formers but, the available data is not sufficient for conclusive decision. In the table, the species that are highlighted with darker gray were sampled only from the ballast waters while; ones highlighted with lighter gray were sampled from both ballast waters and coastal waters. The species that are not highlighted were sampled only from coastal waters.

Table 1: The HABs species observed in Aegean Sea with their functionalities and causatives.

Species	Functionalities		Causatives
Bacillariophyceae (DIATOMS)			
Bellerochea horologicalis		?	
Cerataulina pelagica		Bloom	
Chaetoceros affinis		Bloom	Fish kills
Chaetoceros constrictus		Bloom	
Chaetoceros decipiens		Bloom	
Chaetoceros socialis		Bloom	
Chaetoceros wighamii		Bloom	
Dactyliosolen fragilissimus		Bloom	
Ditylum brightwelli		Bloom	
Eucampia zodiacus		Bloom	
Guinardia delicatula		Bloom	Mucilage clogs fish nets
Guinardia flaccida		Bloom	
Leptocylindrus minimus		Bloom	
Nitzschia longissima		Bloom	Shellfish and finfish kills
Proboscia alata		Bloom	
Pseudo-nitzschia delicatissima group	Toxic		ASP, Domoic acid
Pseudo-nitzschia fraudulenta	Toxic		ASP, Domoic acid
Pseudo-nitzschia pseudodelicatissima	Toxic		ASP, Domoic acid
Pseudo-nitzschia pungens	Toxic	Bloom	ASP, Domoic acid
Pseudo-nitzschia seriata group	Toxic		ASP, Domoic acid
Pseudosolenia calcar-avis	?		
Rhizosolenia setigera		Bloom	
Skeletonema costatum		Bloom	High biomass
Thalassionema frauenfeldii		Bloom	
Thalassionema nitzschioides		Bloom	
Thalassiosira anguste-lineata		Bloom	
Thalassiosira nordenskioeldii		Bloom	
Thalassiosira rotula		Bloom	
Dinophyceae (DINOFLAGELLATES)			
Akashiwo sanguinea		Bloom	

Alexandrium minutum	Toxic		PSP, Ichthyotoxic, Spirolide, Gonyautoxins, also discoloration (Ignatiades *et al,* 2007)
Ceratium furca		Bloom	Discolouration, anoxia
Ceratium fusus		Bloom	Discolouration, anoxia
Ceratium tripos		Bloom	Discolouration, anoxia
Dinophysis acuminata	Toxic	Bloom	DSP, okadaic acid/Dynophysistoxin and derivative toxins, which cause disease in humans and shellfish (JoAnn M. et al, 2005 and 2007)
Dinophysis acuta	Toxic		DSP, Okadaic acid/Dynophysistoxin (JoAnn M. *et al,* 2007)
Dinophysis caudata	Toxic		DSP, Okadaic acid/Palytoxin (JoAnn M. et al, 2007; Wright and Cembella, 1998; Koukaras and Nikolaidis, 2004)
Dinophysis dens	Toxic		DSP, Okadaic acid/Dynophysistoxin (JoAnn M. *et al,* 2007)
Dinophysis fortii	Toxic		DSP, Okadaicacid/Dynophysistoxin/Palytoxin (JoAnn M. et al, 2007; Wright and Cembella, 1998; Koukaras and Nikolaidis, 2004)
Dinophysis pulchella	?		
Dinophysis punctata	?		
Dinophysis sacculus	Toxic		DSP, Okadaic acid (Ignatiades *et al,* 1995)
Dinophysis tripos	Toxic		DSP (JoAnn M. et al, 2007) Dynophysistoxin (Gotsis-Skretas, 2002)
Diplopsalis lenticula	?	Bloom	Unknown toxicity (Gotsis-Skretas, 2002)
Gonyaulax birostris		?	
Gonyaulax polygramma		Bloom	associated with massive fish and invertebrate kills due to anoxia and high sulfide and ammonia
Protoceratium reticulatum	Toxic		Yessotoxin toxin (JoAnn M. *et al,* 2007)
Gonyaulax spinifera	Toxic		Yessotoxin (JoAnn M. et al, 2005; Manuela, 2009)
Gonyaulax turbynei		?	
Gymnodinium catenatum	Toxic	Bloom	PSP, Ichthyotoxic, Gonyautoxins and Saxitoxin (Gárate-Lizárraga et al, 2004)
Gyrodinium spirale		Bloom	
Heterocapsa triquetra		Bloom	(JoAnn M. *et al*, 2007)
Katodinium glaucum		Bloom	
Karenia mikimotoi	Toxic		Gymnocin-A (Satake, 2002)
Lingulodinium polyedrum	Toxic		Yessotoxins (YTXs) (JoAnn M. *et al,* 2007)

Noctiluca scintillans		Bloom	Discolouration, anoxia
Preridinium quinquecorne		Bloom	
Phalacroma mitra	Toxic		DSP (JoAnn M. *et al,* 2007), Okadiac acid (Steidinger & Tangen 1996), Dinophysistoxin-1 (DTX1) (Lee et al. 1989)
Phalacroma rotundatum	Toxic		DSP, Dynophysistoxin (Koukaras and Nikolaidis, 2004), that cause disease in humans and shellfish (JoAnn M. *et al*, 2005)
Prorocentrum compressum		Bloom	
Prorocentrum cordatum	Toxic		DSP, Ichthyotoxic that cause disease in humans and shellfish (JoAnn M. *et al,* 2005), Highly toxic, human fatalities (Shumway, 1990)
Prorocentrum dentatum		Bloom	Discolouration, anoxia
Prorocentrum lima	Toxic		DSP, Ichthyotoxic, Dinophysistoxin (DTX) and their derivatives) (Bravo et al. 2001)
Prorocentrum micans	Toxic	Bloom	DSP, Ichthyotoxic ??, (JoAnn M. *et al*, 2007); also PSP (Shumway, 1990)
Prorocentrum triestinum		Bloom	
Protoperidinium crassipes	Toxic		Azaspiracid toxins because they prey on a toxic species of Azadininum sp and Amphidinium sp. (Magdalena *et al,* 2003)
Protoperidinium depressum	Toxic		Azaspiracid toxins because they prey on a toxic species of Azadininum sp and Amphidinium sp. (Magdalena *et al,* 2003; JoAnn M. *et al,* 2005 and 2007)
Protoperidinium pellucidum		Bloom	(JoAnn M. *et al,* 2005 and 2007)
Scrippsiella spinifera		Bloom	Discolouration, anoxia
Scrippsiella trochoidea		Bloom	Discolouration, anoxia (JoAnn M. *et al,* 2007)
Emiliania huxleyi		Bloom	
Dictyochophyceae			
Dictyocha speculum		Bloom	
Raphidophyceae			
Heterosigma akashiwo	Toxic		Ichthyotoxic, produce an ichthyotoxin that kills fish (Taylor and Horner 1994),
Euglenophyceae			
Eutreptiella gymnastica		Bloom	Discolouration, anoxia
Cyanophyceae			
Oscillatoria sp	Toxic		Debromoaplysiatoxin (Dietrich and Hoeger, 2005)

4. Discussion and Conclusion

Prior to discussion, a special note will be beneficial as an emphasis on the fact that HABs incidents in Mediterranean has usually not monitored within a subject specific program, but rather included into the environmental monitoring programs for coastal waters. Such strategy can be considered reasonable in managerial aspect since it is highly linked with cost-benefit evaluations, particularly when a risk management approach is not integrated in it.

A typical case is the monitoring programme of İzmir Bay which was initiated and funded by Metropolitan Municipality in early 1980s, and it has been continued since mid 1990s with varying temporal scale mainly which were bimonthly, seasonal and annual. The phytoplankton species list for Izmir Bay was thus developed gradually. Nevertheless, a discrete research project in which monthly sampling was carried out has provided 38 new records for the list (Bizsel and Bizsel, 2004; Bizsel and Nezan, 2007). Considering the short doubling time of microalgae in addition to the activities creating favorable environmental pressures such as species translocations by intensive maritime traffic (*e.g.,* ballast waters) and by discharges and wastes promoting nutrient enrichment, appearance of new species record for Izmir Bay should not be perceived as an unexpected consequence. The transport of HABs species over long distances becoming easier and occurs through ship ballast water, aquaculture facilities, the transfer of seafood stocks, increased recreational boating, and surprisingly to new ways such us the attachment to floating debris (Masó *et al.,* 2003). Moreover, the drawbacks of low temporal resolution in the conducted sampling surveys for determining the actual flora native to the bay is not a less important factor that inhibits to decrease the probability of occurrence of non-sampled species. These ascertainments address a possible scenario on HABs dynamics in Izmir Bay. The increasing trends observed during this long period of monitoring do presumably reflect the actual frequency of occurrence of HABs incidents which had been gone on long before the onset of monitoring program. Considering the fact that HABs incidents are not always visible, it is quite likely that the increased frequency observed can result due to the improved sampling and diagnosis efforts.

A concrete evidence can be obtained to support above mentioned scenario is simply to recall that the first recorded toxic phytoplankton species in Izmir Bay was *Alexandrium minutum* Halim (exceeding 8.106 cells/l) in April-May 1983, and it was found in the harbor region of the inner section of the bay, during a red tide event (Koray and Büyükışık 1988). Today, there are almost 40 HABs species which all are listed in Table1. Before early 1980s, the plankton studies were quite scarce and usually represent highly restricted areas.

In Table 1, there are 74 species belonging to 6 taxonomic divisions. 28 out of this total are diatoms (Bacillariophyceae) and of 42 are dinoflagellates (Dinopyceae). Each of other four divisions is represented by single species. 15 of them (20,3%) are only sampled in ballast waters in Aegean Sea while 47 of them (63,5%) are sampled both in ballast waters and coastal waters. The distribution of the latter group is not restricted with Aegean Sea, but all Turkish coastal waters. The final group is represented by 12 species (16,2%) which are observed only in coastal waters. These figures demonstrate that 83,8% of listed 74 species are linked with the ballast waters.

In another perspective provided by the data compiled from the published studies in Table 2, shows that there are 34 HABs species recorded from spring season in Izmir Bay during the period of 27 years between 1983 and 2010.

Table 2: List of HABs which occurred in Izmir Bay during the period of 27 years between 1983 and 2010.

1983	**1994**	**1998**	**2010**	**#of Reappearance**
Cylindrotheca closterium		*Cylindrotheca closterium*	*Cylindrotheca closterium*	**3**
		Nitzschia longisima	*Nitzschia longisima*	**2**
Pseudo-nitzschia pungens		*Pseudo-nitzschia pungens*		**2**
	Skeletonema costatum		*Skeletonema costatum*	**2**
Thalassiosira allenii	*Thalassiosira* sp.	*Thalassiosira* sp.	*Thalassiosira* sp.	**4**
Thalassiosira anguste-lineata				**1**
Thalassiosira rotula		*Thalassiosira rotula*		**2**
Alexandrium minutum		*Alexandrium minutum*		**2**
Ceratium sp	*Ceratium* sp	*Ceratium sp*	*Ceratium* sp	**4**

Gonyaulax polyedra				**3**
		Gonyaulax sp.	*Gonyaulax* sp.	
Gonyaulax spinifera			*Gonyaulax spinifera*	**2**
		Karenia mikimotoi	*Karenia mikimotoi*	**2**
		Gyrodinium spirale	*Gyrodinium spirale*	**2**
		Heterocapsa sp	*Heterocapsa* sp	**2**
		Katodinium glaucum	*Katodinium glaucum*	**2**
Noctiluca scintillans	*Noctiluca scintillans*	*Noctiluca scintillans*	*Noctiluca scintillans*	**4**
		Phalacroma rotundatum	*Phalacroma rotundatum*	**2**
Prorocentrum micans	.	*Prorocentrum micans*	*Prorocentrum micans*	**4**
		Prorocentrum cordatum	*Prorocentrum cordatum*	**2**
Prorocentrum triestinum		*Prorocentrum triestinum*	*Prorocentrum triestinum*	**3**
	Prorocentrum sp			
Protoperidinium sp.	*Protoperidinium* sp.	*Protoperidinium* sp.	*Protoperidinium* sp	**4**
Scrippsiella trochoidea	*Scrippsiella trochoidea*	*Scrippsiella trochoidea*	*Scrippsiella trochoidea*	**4**
		Heterosigma akashiwo	*Heterosigma akashiwo*	**2**
	Euglena viridis			**1**
Eutreptiella		*Eutreptiella*	*Eutreptiella*	**3**

gymnastica		*gymnastica*	*gymnastica*	
		Ebria tripartita	*Ebria tripartita*	**2**
Pyramimonas propulsum				**3**
		Pyramimonas sp	*Pyramimonas* sp	
		Cryptophyceae	*Cryptophyceae*	**2**
Mesodinium rubrum		*Mesodinium rubrum*		**2**
17	***8***	***25***	***23***	

Although the data is composed only by four discrete snapshots (Koray and Büyükışık, 1988; Metin, 1995; Bizsel *et al.,* 2002; Tumer, 2012), it provides some important information. In the beginning there were only 17 species identified in 1983 somehow which reduced to 8 in 1994 and then increased almost three fold in 1998 and remain at this level in 2010. Furthermore, the frequency of appearances of these species demonstrates that there are only four species (12,9%) which were observed once. Most of them are observed twice (54,8%). The percentages of species observed three times and four times are equal 16,1% which they consist 32,3% of the total. This means that one third of HABs species are resident in Izmir Bay. Considering the facts that 74 species the 1998 period indicated that the main red tide causative species is *N. scintillans* observed in Aegean Sea, 34 of them were able to be recorded in four discrete samplings carried out within 27 years, the likelihood of observing higher numbers has to be remarkably higher. However, it is not possible to test this possibility without creating a time series data set having at least monthly sampling resolution and a proper spatial coverage.

Among the species listed in Table 2, the most causative organism of dense red-tide in Izmir Bay is particularly *Noctiluca scintillans.* As shown in Figure 1, the samples from the orange and reddish patches during and this species had very strong correlation with ammonium (Bizsel *et al.,* 2002).

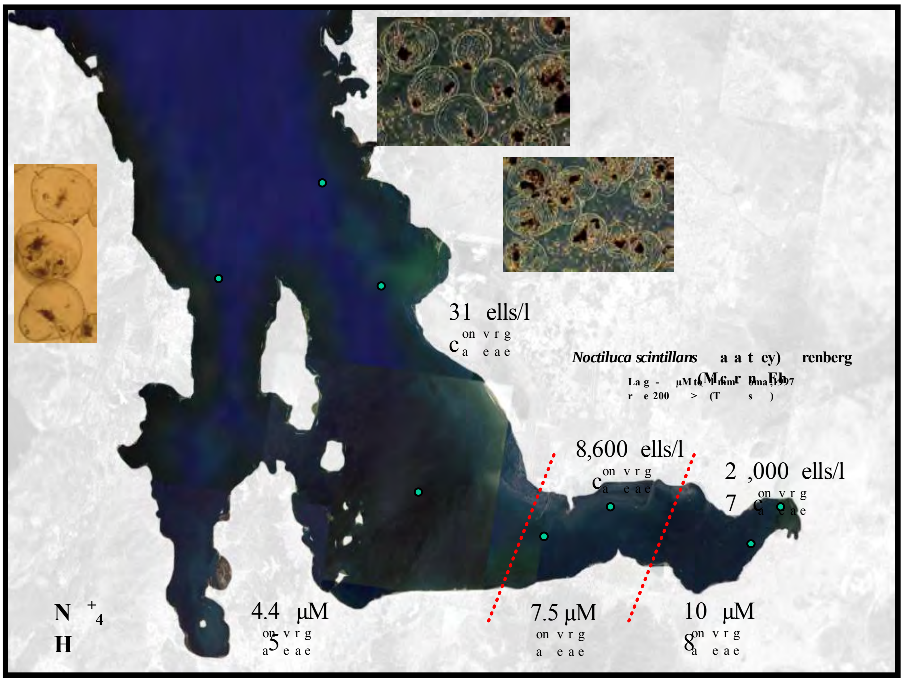

Figure 1. The correlation between NH4 concentration and *Noctiluca scintillans* abundance in different segments of Izmir Bay.

Same authors also reported to Izmir Metropolitan Municipality that the discolourations have also been occurred by *Prorocentrum micans* in 2001*, Scrippsiella trochoidea, Alexandrium minutum and Eutreptiella gymnastica, Dinophysis rotundata*, *Nitzschia longisima*, and *Prorocentrum dentatum* in 1999 and *Scrippsiella spinifera* in 2006*, Gonyaulax* sp.*, Cylindrotheca closterium,* and *a* Cryptophyceae species in 2010. In April 1999, red tide and then olive green short-term patchy tides (2-3 days) and afterward green tide were observed by the high abundance of *Eutreptiella gymnastica*. In September 1999, a brown tide occurred by *Prorocentrum dentatum*.

After the efforts spent since 1980s, it is unfortunate and highly engrossing even not to be able to evaluate precisely whether some species are indeed restricted in their distribution or their occurrences simply reflect the lacks or gaps in the studies carried out in some bays along the coasts of Aegean Sea and Mediterranean in general, despite the fact that the understanding HABs requires more complicated knowledge and information, as will be addressed briefly in the following.

When the factors enhancing the HABs incidents are considered slightly closer, the expansion of large ports and the construction and development of the accompanying coastal infrastructures have resulted in the provision of sheltered water areas which increases the occurrence of HABs. Moreover, the proliferation of ports which reduces the distances between favorable areas to be colonized can increase the species translocation. This is coupled by the ability of many species, including those that form HABs, to develop resistant stages (*i.e.,* resting cysts) viable in the sediments for long time. Then these areas act as a "seed reservoirs" of HABs species due to the accumulation of resting stages (Garcés *et al.,* 2010). This benthic stage of these resting cysts sinks and remains viable in the sediments for several years. These resting cysts provide a reservoir of potential diversity of species ready to produce a bloom again. The species translocation through ship ballast water or aquaculture facilities, dormant stages also play a prominent role due to their resistance and longevity. Factors that actually trigger growth of the species likely include the combined influences of water temperatures, solar irradiance, and day length. Once the environmental conditions allow an *Alexandrium minutum* bloom, as was the case in Izmir Bay in 1983, the formation of resting cysts appears to be a continuous process, involving a minor fraction (<1%) of the population during all bloom phases (Garcés *et al.,* 2004).

Moreover, the question should also comprise the relationship between eutrophication and HABs. While the scientific community agrees, in general, on the key role of coastal over-enrichment as significantly contributing to the increase of HABs, in only a few cases has this relationship been thoroughly proven, since the link between HAB occurrence and marine coastal eutrophication is not direct (Masó and Garcés, 2006). It is obvious that a high-biomass bloom requires sufficient exogenous nutrients to be sustained (Heisler *et al.,* 2008) but it is difficult to establish a connection between eutrophication and toxic blooms, as there may not be a huge increase of the accordant species and its presence even at low levels can produce harmful effects. Instead, it is necessary to appreciate the complex links between HABs and nutrient loading. This, in turn, implies an understanding of the physiological requirements of HAB species and their mechanisms of nutrient acquisition (Jauzein *et al.,* 2008a, Jauzein *et al.,* 2008b), as the rate of nutrient supply will not necessarily correlate with the rate of nutrient assimilation, for instance some phytoplankton species have developed adaptive strategies such as more efficient nutrients uptake or even mixotrophy. The typical examples for mixotrophy are dinoflagellates. In any case, newly created microhabitats in the coastal area where high nutrient inputs coincide with reduced natural hydrodynamic regimes are favoring some phytoplankton species among them those that can cause HABs.

The damage caused by these blooms and the lack of a clear understanding of their occurrence underline the importance of establishing appropriate monitoring systems to gain the knowledge needed to implement appropriate preventative as well as prophylactic measures to impede these outbreaks. Blooms can comprise different species. In the Mediterranean Sea, data are sparse for certain key taxa, and there are still a large number of undescribed species. Better taxonomy, more thorough local and regional datasets, as well as long-term studies are required since these programs are absent or unavailable for many Mediterranean countries, including Turkey. Even for naturally occurring blooms, data on the key biological processes influencing bloom dynamics, such as vegetative growth and loss rates due to mortality, are almost non-existent. These gaps in our knowledge of the life cycles, ecophysiology, and identification of bloom-forming species have hindered the development of predictive models and therefore the ability to anticipate HAB events. The gaps of knowledge hinder our ability to predict what will be the trends regarding generation of HABs. In a general context, the whole Mediterranean Sea will continue to undergo a general oligotrophication due to fewer continental contributions and a greater stability of the water column in a global warming scenario. However, we cannot predict to what extent this process will be counterbalanced by more frequent extreme weather events. Knowledge in how multiple impacts will interact is very limited.

Together, these facts corroborate a scenario in which the risk of HABs in the Mediterranean has increased by (at least) an order of magnitude in the last 50 years and the final tendency is growing. Human-induced climatic change has also been mentioned as a contributing factor, but the lack of long-term monitoring makes it a difficult or almost impossible task, at least at the present time, to reach any conclusions regarding climate change and the increasing frequency of HABs in the Mediterranean Sea (Garcés *et al.* 2004).

Regarding the frequency of HAB incidents and appearances of new species, a dynamic HAB network which is capable to collect updated data and react promptly against episodic progresses in terms of forecast and risk mapping is inevitable because the inferences focusing on public health, economics, and social problems beside the ecological ones have increasingly been needed all around the Mediterranean coasts. Such an achievement enables us to build efficient tools for controlling HABs events and mitigating the relevant adverse consequences.

Last but not the least, the presence of global efforts towards building the capacity briefly outlined above has been spent for years. In the UNESCO-IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB) in Paris, on 12–14 April 2011, a series of resolutions has been decided and announced. There are seven resolutions each framing most important actions to be initiated at once:
(i) Regional HAB Programme Development,
(ii) Biotoxin Monitoring, Management and Regulations,
(iii) The GEOHAB Research Programme,
(iv) Harmful Algae and Desalination of Seawater,
(v) reviser terms of reference for the Task Team on Algal Taxonomy,
(vi) Harmful Algae and Global Change, and

(vii) Harmful Algae and Fish-killing Marine Algae.

The special emphasis on the need for focusing on the activities related with the transfer and introduction of HAB species by human activity such as shipping (ballast water) has also be declared by the Panel.

Consequently, these tasks have already been delivered to the governments in a refined guidelines provided by international experts reflecting the available global capacity and the needs to improve it.

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ASSESSMENT OF HEAVY METAL POLLUTION IN THE AEGEAN SEA

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1. Introduction

Pollution by heavy metals causes considerable environmental concern due to their persistence, toxicity, and potential to accumulate in biota (Ansari *et al*., 2004). Heavy metals are continuously introduced in the coastal zone by land-based pollution sources primarily in areas near cities, ports, river mouths, and industries. Indeed, more than 90% of the heavy metal loads received by coastal aquatic systems are bound to suspended particulate matter and sediments (Calmano *et al*., 1993), accumulating through sedimentation in aquatic sediments. Metals in sediments are not permanently bound; through a variety of biological (e.g. activities of bottom-dwelling fish) and physicochemical processes (e.g. pH changes, sediment oxidation, and heavy metal complexation by anions like chloride), these heavy metals may effectively be recycled back into the overlying water phase (Foerstner and Wittmann, 1983; Calmano *et al*., 1993). Since sediments act as the main sinks and sources of metals in the marine environment, they are widely used as indicators of metal pollution (Förstner and Salomons, 1980; Szefer *et al*., 1996). On the other hand, metal levels in marine biota provide information on metal bioavailability, thus their measurement has direct ecotoxicological relevance and is essential for pollution assessment (Rainbow, 1995; Walker *et al.,* 2006).

Many studies have documented that short-term or long-term exposure to elevated toxic metals could depress the enzyme activity, change the activity of microbes, as well as reduce the microbial diversity (for example, Wang *et al*., 2007). In terms of human populations, more attention has been paid to the adverse effects of toxic metals, transferred and deposited in human bodies through the food chain (Valko *et al*., 2006).In the marine environment, metals such as iron, vanadium, copper, and zinc are essential for certain biochemical reactions in organisms, but even in moderately contaminated estuaries these metals contribute to stress in marine biota. By virtue of their toxic and bioaccumulative properties both cadmium and mercury are regarded as 'Black List' substances, while lead is on the 'Grey List'. These elements have little or no biochemical function and, while tolerable in minute quantities, exhibit toxic effects above critical concentrations. Mercury has a complex marine chemistry and exists in various forms, such as inorganic mercury, organically complexed mercury (with natural dissolved organic carbon), as a dissolved gas, Hg^0, and as the methylated species monomethyl mercury (MMHg) and dimethyl mercury (DMHg). Both MMHg and DMHg are present in the water column in sediments and in the tissues of marine organisms. Thus, depending on their physicochemical state or bioavailability, metals will impact upon different parts of the marine food web and in some cases bioaccumulation and/or biomagnifications occurs, which may, ultimately, expose humans to a potential health hazard (Steele *et al.,* 2010).

2. Description of the Aegean Sea

Aegean Sea, Greek Aigaíon Pélagos, Turkish Ege Denizi, a part of the Mediterranean Sea, located between the Greek peninsula on the west and Asia Minor on the east. About 612 km long and 299 km wide, it has a total area of some 215000 km^2. The Aegean is connected through the straits of the Dardanelles, the Sea of Marmara, and the Bosporus to the Black Sea, while the island of Crete can be taken as marking its boundary on the south.

The maximum depth of the Aegean is to be found east of Crete, where it reaches 3544 meters. The rocks making up the floor of the Aegean are mainly limestone, though often greatly altered by volcanic activity that has convulsed the region in relatively recent geologic times.

North winds prevail in the Aegean Sea, although from the end of September to the end of May, during the mild winter season, these winds alternate with southwesterlies. Water temperatures in the Aegean are influenced by the cold-water masses of low temperature that flow in from the Black Sea to the northeast. The sea surface temperature in the Aegean ranges from about 16 to 25 °C, varying with location and time of year.

The Aegean Sea, like the Mediterranean in general, is the most impoverished large body of water known to science. The nutrient content, as indicated by the amount of phosphates and nitrates in the water, is on the whole poor. The less saline waters coming from the Black Sea have a distinct ameliorative influence, but the role of their fertility in the Mediterranean in general has been little studied. Generally, marine life in the Aegean Sea is very similar to that of the northern area of the western basin of the Mediterranean (http://global.britannica.com/place/Aegean-Sea).

3. Metals in Sediments

Sediments play a major role in the overall fluxes of trace elements in coastal systems, acting occasionally as a source and/or sink. Metals may be recycled several times through the sediment-water interface before being permanently stored in sediments or released to the overlying waters (Sakellari *et al*., 2011). Thus, marine sediments are commonly used as environmental matrices in chemical monitoring programs. The concentrations of a set of metals in sediment from Aegean Sea are reported in Table 1.Aközcan and Görgün (2013) determined trace metal levels in surface sediments collected from two important areas (Izmir Bay and Didim) from the eastern Aegean coast and trace metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) were measured in sediment. The trace metal results showed that the Izmir Bay is facing trace metal pollution.

Uluturhan *et al.* (2011) investigated heavy metal levels in sediment of the Homa Lagoon which is one of the most productive lagoons and commercial important active fish trap in the Eastern Aegean Sea. The results were used to evaluate possible ecological risks that could be a problem for the environment of the lagoon in the future. Sediments from Homa Lagoon were most toxic for Ni because they exceeded the TEL and PEL values.

Christophoridis *et al.* (2009) examined sediment and water samples collected from the Gulf of Thermaikos and the Bay of Thessaloniki in order to determine the concentrations of Zn, Cu, Pb and Cr. The highest metal levels were found along the shoreline of the Bay of Thessaloniki, reflecting long-term exposure to anthropogenic activities. Enrichment Factors reveal the anthropogenic sources for chromium and lead. The majority of the sediment samples can be occasionally and frequently associated to toxic biological effects, according to the effect-range classification for Zn, Cu and Pb.

The Bay of Gökova in Southeastern Aegean Sea is important by the potential of agricultural, municipal, and tourism activities. The levels of Cd, Cu, Fe, Pb, and Zn were measured in suspended particulate matter (SPM) and sediments (Demirak *et al.*, 2012). It has been identified that the metal concentrations in the creeks are higher than the metal concentrations in the marine environment. It has also been observed that the concentrations of Pb, Cd, and Cu have been measured as higher in summer period than the winter however no significant differences were found seasonally for Fe and Zn. The results show that some heavy metals are caused by the agricultural, municipal, and tourism activities operating in the coastal areas, and they are transported from the creeks to the Gökova Bay by suspended particulate matter.

Marine sediment contamination was evaluated in a set of sediment specimens collected from Izmir Bay (Turkey) and from Mytilene Harbor (Greece) in the Aegean Sea by Kostopoulou *et al.* (2013). Eight sediment sample from Izmir and seven sediment sample from Mytilene were analyzed for their content in different classes of contaminants, i.e. inorganics, organic carbon. Significantly higher levels of inorganic contaminants were detected in Izmir vs. Mytilene sediment, and the highest inorganic contamination was monitored in the inner part of Izmir Bay. This was the case for Al, As, Cr, Cu, Fe, Li, Mn, Pb, Ti and Zn. The overall results point to higher pollution status in Izmir Bay, especially in the innermost sampling sites, compared to Mytilene Harbor.

Aliağa Bay is one of the most important maritime zones of Turkey where shipping activity, shipbreaking industry, steel works and petrochemical complexes exist together. Concentrations of heavy metals and organic carbon in sediment of the Aliağa Bay were investigated to evaluate an environmental risk assessment from metals contamination in 2009–2010 (Neşer *et al.*, 2012). Comparison of the metal concentrations with average shale and Mediterranean background levels revealed that most of the samples from the Aliağa were polluted with Hg, Cd, Pb, Cr, Cu, Zn, Mn and Ni. It was found that Hg, Pb, Cu, Zn and Ni levels in Aliağa Bay exceeded the PEL values.

Table 1. The range of metal concentrations (µg g^{-1} dry weight) found in sediments from different parts of Aegean Sea

Region	Cd	Cr	Cu	Hg	Pb	Zn	References
E Aegean	0.01-0.1	19-231	3-32	0.01-0.1	2-51	9-84	Akcali, Kucuksezgin(2011)
Izmir Bay	0.02-0.5	155-385	32-82	0.3-0.8	81-173	105-265	Özkan (2012)
Saronikos	190-1763	264-860	195-518	-	521-1263	409-6725	Galanopoulou et al. (2009)
Candarli G.	-	16-71	3-35	0.1-1	15-138	50-358	Pazi (2011)
Nemrut B.	0.01-0.3	36-99	10-44	2-10	22-89	75-271	Esen et al. (2010)
Kavala G.	0.03-2	23-185	1-154	0.03-1	18-203	48-1024	Sylaios et al. (2012)
N Aegean	0.1-39	5.2-76	2-119	0.03-0.4	9-275	12-538	Papastergios et al. (2010)
Izmir Bay	0.01-0.8	19-316	2-109	0.1-1	3-119	14-412	Kucuksezgin et al. (2011a)
E Aegean	0.01-0.1	19-555	10-42	0.1-0.2	4-48	48-121	Uluturhan (2010)
Izmir Bay	-	23-112	5-66	-	8-82	22-196	Atalar et al. (2013)
Aliaga B.	0.1-4	65-264	20-703	0.32-7	91-751	86-970	Neşer et al. (2012)
E Aegean	nd-1.1	30-190	13-96	0.2-0.6	9-105	47-435	Kostopoulou et al. (2013)
NEAegean	-	23-221	3-78	-	9-113	37-248	Karditsa et al. (2014)
W Aegean	-	109-371	18-47	0.01-0.3	24-59	68-124	Tsangaris et al. (2013)
Izmir Bay	0.2-0.4	210-300	32-70	-	36-62	99-260	Atgin et al. (2000)
Izmir Bay	0.01-1	19-316	2-109	0.10-1	7-119	14-412	Kucuksezgin et al. (2004), (2006)
Saros G.	-	-	6-44	0.01-0.1	2-80	23-154	Sarı&Çağatay (2001)
E Aegean	-	13-387	4-80	-	-	28-205	Ergin et al. (1993)
E Aegean	0.03-0.5	40-154	5-86	-	21-93	13-230	Aloupi&Angelidis (2001)
N Aegean	-	213-364	51-206	-	131-2233	159-927	Stamatis et al. (2002)
Izmir Bay			4-71			26-295	Kontas (2008)
Mean C.*	0.20	100	55	0.08	13	70	Taylor (1964)
Medit. BG**	0.1-2	15	15	0.34	25	50	UNEP(1978), Whitehead et al. (1985), MAP (1987)

* Mean C: Mean crustal, ** Medit. BG; Mediterranean background

Kaymakcı Basaran *et al.* (2010) investigated potential effects of the fish farms on sediment around Salih Island in the Güllük Bay (Turkey) where seasonal samplings were performed from October 2001 to August 2002. Heavy metals (Zn, Cu and Fe) were measured in sediment samples. Results indicated that concentrations of heavy metals were within the range of tolerable levels for the marine ecosystem.

The levels of heavy metals were determined in surface and core sediments from the Izmir Bay in 2009 by Atalar *et al.* (2013). The highest concentrations of As, Cr, Cu, Ni, Pb and Zn were found in the inner bay due to industrial activities. In contrast, maximum levels of Mn, Co, Fe and Al were observed in the outer bay, due to geochemical structure. Cu, Pb, Zn, Ni, As, Cr and Co levels in the upper layer of core sediments were higher than the mean background values of bottom sediments. It was found that the sediments in Izmir Inner Bay were generally polluted heavily with Cu, As, Ni, Cr, Pb and moderately with Zn according to the numerical SQG of the USEPA.

Uluturhan (2010) determined heavy metal pollution in the two gulfs of the Aegean Sea; Saros and Gökova Gulfs. The results showed that the sediments of Saros and Gökova gulfs were polluted with Pb, Cr, Zn, Mn, Ni and Pb, Cr, Ni, Mn, respectively. The sediments were noted to be not contaminated with Hg, Cd, and Cu in all areas.

The levels of metals [Cd, Pb, W, Zn, Mn, As, Se, Cr, Cu, and organic carbon (Corg)] have been determined by Galanopoulou *et al.* (2009) in the surficial sediments of Keratsini harbor, Saronikos Gulf, Greece. The results revealed highly elevated Cd, Pb, W, Zn, As, Se, Cr, Cu, and Corg values.

Sakellari *et al.* (2011) assessed the remobilization of Cu, Cd and Zn in sediments of three selected coastal microenvironments of the Aegean Sea. The comparatively high zinc levels measured in the pore waters (394 nM), exceed considerably those in the overlying seawater (12.5 nM determined by DGT; 13.5 nM total), resulting in the formation of a strong concentration gradient at the sediment-water interface.

Pazi (2011) investigated heavy metal levels (Fe, Mn, Ni, Cu, Zn, Pb, Hg, Cr, Al, As) in surface sediments in the Çandarlı Gulf in order to understand metal contamination due to urbanization and economic development in Çandarlı region, Turkey. The samples were collected by box corer during 2009 to assess heavy metal pollution. Pollution indices showed that Hg, Zn, and Pb contamination existed in the entire study area.

Surface sediments collected from nine stations in Nemrut Bay, Aegean Sea were analyzed for trace metals (Hg, Cd, Pb, Cr, Cu, Zn, Mn, Ni, Fe, As, and Mg) by Esen *et* *al*. (2010). The analyses revealed significant anthropogenic pollution of Hg, Pb, Zn, and As in the surficial sediments of Nemrut Bay.

The surface sediment samples from Izmir Bay were collected during 1997–2009 (Kucuksezgin *et al.,* 2011a). The concentrations were generally higher than the background levels from the Mediterranean and Aegean except Cd and Pb levels gradually decreased. Maximum metal enrichment was found for Hg in the outer bay, while Pb indicated maximum enrichment in the middle-inner bays.

Metal concentrations were determined in surface sediments in a shallow semi-enclosed bay, Pagassitikos Gulf, Aegean Sea by Tsangaris *et al*. (2013). Cu, Zn, Pb, Hg, and As levels in sediments were enriched close to point sources of pollution, i.e., Volos Port and cement plant.

Sediment samples were collected to detect their metal contents in order to gain more information on the environmental conditions and possible bioaccumulation patterns (Aydin Onen *et al.* 2011). The order of metal concentrations in sediment decreased in the following order Fe > Mn > Zn > Cu > Pb > Cr > Hg > Cd.

Kontas (2012) investigated the concentrations of trace metals (Cu, Zn, Mn, Ni, and Fe) from suspended particulate matter (SPM) in Izmir Bay (Eastern Aegean Sea). Metal concentrations in SPM were Cu, 0.36-2.19; Mn, 0.07-11.3; Ni, 0.43-7.81; Zn, 7.33-269; Fe, 1.00-266 $\mu g\ dm^{-3}$.

Batki *et al***.** (1999) investigated levels of trace metals (Cd, Pb, Cu, Zn, Cr) in different chemical fractions of sediments in the Aegean Sea during 1994. The highest levels of Cd, Cu, Zn and Cr were found in inner part of Izmir Bay. Maximum Pb concentration was measured in Edremit Bay.

4. Metals in Biota

In the monitoring of coastal environmental quality, emphasis has been placed on the use of selected biological species, termed biomonitors, as it allows the evaluation of biological available levels of trace elements in the ecosystem. Biomonitors should have several desirable characteristics, most importantly to be strong net accumulators of trace elements and to reflect their ambient bioavailabilities. Fish, mussel and seaweed species have been considered excellent biomonitors of the bioavailable trace element in seawater, as they accumulate elements from solution several times their levels of surrounding seawater (Rainbow, 2006, Malea and Kevrekidis 2014). Bibliographical data on metal concentrations ($\mu g g^{-1}$) of biota from different regions of Aegean Sea were given in Table 2.

Determination of metal levels in muscles and livers of twelve fish species from Aegean Sea and Mediterranean Sea by ICP-AES was made by Türkmen *et al.* (2009). The levels of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in muscles of fish were <0.01–0.39, <0.01–0.45, 0.07–1.48, 0.51–7.05, 9.18–136, 0.18–2.78, 0.03–1.72, 0.21–1.28 and 3.51–53.5 mg kg^{-1}, respectively. Metal levels in muscles were generally lower than those in livers. The estimated values of all metals in muscles of fish in this study were below the established values. Therefore, it can be concluded that these metals in edible parts of the examined species should pose no health problems for consumers.

The fish samples from Izmir Bay were collected during 1997–2009 (Kucuksezgin *et al*., 2011a). The levels of fish tissues were lower than the results reported from polluted areas of the Mediterranean.

Kucuksezgin *et al.,* (2011b) evaluated TBT, dibutyltin and monobutyltin levels in barnacles, mussels and fish along the Eastern Aegean coastline. The highest concentrations of TBT, DBT and MBT were observed in the barnacles which had been sampled in marinas and harbors. Barnacles have high potential as biomonitors for the presence of organotin in the Aegean Sea.

Investigations by Giannakopoulou and Neofitou (2014) were conducted in the bioaccumulation of heavy metals for both a benthic (*M. barbatus*) and a benthopelagic fish species (*P. erythrinus*). The aim of this study was to examine the concentration levels of four metals in the body tissue of two fish species, in Pagasitikos Gulf in Greece. Cr, Cu, Zn and Cd concentrations were measured in muscle, gills, vertebral column, and in the "remaining fish sample".

Aydin *et al.* (2015) investigated the spatial distribution of dinoflagellate cysts to understand the impact of industrial pollution on the surface sediment of Izmir Bay, Turkey. The highest cyst concentration was recorded in the inner part of the bay. Cyst concentration ranged between 384 and 9944 cyst g^{-1} dry weight of sediment in the sampling area. Sediment metal concentrations were determined.

.Pell *et al.* (2013) determined the content of total arsenic and arsenic compounds in the dominant seaweed species in the Thermaikos Gulf, Northern Aegean Sea in samples collected in different seasons. Total arsenic concentrations in the seaweeds ranged from 1.39 to 55.0 mg kg^{-1}.

Tepe (2009) determined the concentrations of cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, and zinc in muscles and livers of eight fish species sampled from the Aegean and Mediterranean seas of Turkey. Metal concentrations in edible parts of fish species were 0.03-0.37 for Cd, 0.02-0.42 for Co, 0.15-1.78 for Cr, 0.17-1.11 for Cu, 11.0-33.4 for Fe, 0.02-0.89 for Mn, 0.22-4.03 for Ni, 0.22-0.64 for Pb, 2.88-10.9 mg kg^{-1} for Zn, respectively.

Colakoglu *et al.* (2012) investigated concentrations of eight heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in economically important bivalve species: oyster (*Ostrea edulis*), wedge clam (*D. trunculus*), manila clam (*R. philippinarium)* and warty clam (*V. verrucosa*) from the Marmara and Aegean seas. Samples were collected seasonally between 2008 and 2009. Metal levels of bivalves were found in the following ranges: As 0.02-3.40, Cd 0.02-2.80, Cr 0.19-0.82, Cu 0.82-25.06, Hg < LOD-0.12, Ni 0.09-0.73, Pb 0.05-4.16 and Zn 6.85-899 mg kg^{-1}. The most abundant elements were Zn>Cu>As.

Metal concentrations were determined in transplanted mussels in a shallow semi-enclosed bay, Pagassitikos Gulf, Aegean Sea (Tsangaris *et al.* 2013). Concentrations of metals in transplanted mussels were comparable to those reported in Mediterranean areas.

Kucuksezgin *et al.* (2010) examined the heavy metal contents in *T. decussatus* (carpet shell clam) from Izmir Bay (Eastern Aegean). Bivalve mollusks were sampled on January, March, July, and October 2007 in the Izmir Bay. The concentration of heavy metals in *T. decussatus* from Izmir Bay were Hg 0.044-0.13; Cd 0.026-0.24; Pb 0.38-1.2; Cr 2.3-3.7; Cu 6.4-8.4; Zn 56.0-81.8, and Ni 8.1-9.6 mg kg^{-1} (dry weight).

Within the framework of the MYTITURK project, Kucuksezgin *et al.* (2013) assessed heavy metals contaminations in transplanted mussels in eight different bays from the Eastern Aegean coast. According to world health authorities, the concentration of heavy metals in mussels for the study area can generally be considered not to be at levels posing a health risk except Zn.

Aydin Onen *et al.* (2011) This biomonitoring study presents the spatial and temporal distributions of heavy metals in the soft tissues of a major fouling species *A. amphitrite* living on hard substrate at different sites along the eastern Aegean coast. *A. amphitrite* has been chosen as a strong candidate for monitoring heavy metals. The order of metal concentrations in barnacles decreased in the following order Cu>Fe>Zn>Mn>Cd>Cr> Pb>Hg.

Table 2. Levels of heavy metals (as µgg^{-1}) found in biota taken from Aegean Sea

Organism	As	Cd	Cr	Cu	Hg	Pb	Zn	References
Fish (ww)		nd-0.4	0.1-2	0.5-7	-	0.2-1	4-54	Türkmen *et al.* (2009)
Fish (ww)		0.10-10	21-270	178-568	14-500	3-478	2157-3832	Kucuksezgin *et al.* (2011a)
Fish (dw)		0.2±0.1	1.9±1	3.2±1	-	-	27±13	Giannakopoulou&Neofitou (2014)
Phytoplank (dw)		0.1-0.3	71-175	11-58	0.1-0.5	18-34	42-216	Aydin *et al*. (2015)
Algea (dw)	1-55	-	-	-	-	-	-	Pell *et al*. 2013
Fish (ww)	-	-	-	-	4.4-221	-	-	Gonul&Kucuksezgin (2007)
Fish (ww)	-	0.03-0.4	0.2-2	0.2-1	-	0.2-1	3-11	Tepe (2009)
Bivalve (ww)	0.1-3	0.04-0.1	0.2-0.3	0.9-3	<0.05	0.01-0.3	9-14	Colakoglu et al. (2012)
Bivalve (dw)	-	1.7-2.2	2.4-8	6.6-10	0.2-0.3	0.9-2	228-364	Tsangaris *et al*. (2013)
Fish (ww)	-	0.10-10	22-312	121-568	4.5-520	1-491	2157-6971	Kucuksezgin *et a*l. (2006)
Bivalve (dw)	-	-	0.1-0.2	3.6-5	0.01-0.02	0.07-0.1	18-29	Kucuksezgin *et a*l. (2008)
Bivalve (dw)		0.03-0.2	2.3-4	6-8	0.04-0.1	0.38-1	56-82	Kucuksezgin *et al*. (2010)
Bivalve (dw)	-	0.5-3.4	1.5-4	4-9	0.1-0.2	1.1-4	108-349	Kucuksezgin *et al.* (2013)
Barnacle (dw)	-	5.0-20	2-14	28-2371	0.02-0.76	1.0-20	179-846	Aydin Onen *et a*l. (2011)
Bivalve (dw)	-	0.3-5.6	-	9.4-98	-	4.6-14	165-866	Ozsuer&Sunlu (2013)
Bivalve (ww)	-	0.3-0.5	-	1.4-2	-	0.80-2	20-37	Sunlu (2006)
Bivalve (ww)	2-3	-	-	-	-	-	-	Kucuksezgin *et al.* (2014)
Fish (ww)	1-22	-	-	-	-	-	-	Kucuksezgin *et a*l. (2014)
Macroalgae (dw)	1-46	0.02-1.1	2.8-53	2-27	-	0.97-28	70-219	Malea& Kevrekidis (2014)
Zooplankt. (dw)	-	-	-	27-293	-	-	81-2534	Kontas (2008)
Fish (ww)	-	-	-	0.2-7	-	-	1.7-30	Kontas (2012)
Fish (liver ww)	-	nd-0.17	0.01-1	0.01-1	-	-	0.02-1	Katalay *et al*. (2005)

Ozsuer and Sunlu (2013) compared the levels of the trace metals zinc (Zn), cadmium (Cd), lead (Pb) and copper (Cu) in the bivalve *Lithophaga lithophaga* from Izmir Bay (Aegean Sea) between 2001 and 2011. Median values of trace metals for all seasons in 2011 were 244.67 mg Zn kg^{-1}, 1.09 mg Cd kg^{-1}, 7.64 mg Pb kg^{-1} and 56.03 mg Cu kg^{-1} as dry weight. Mean trace metal concentrations in individuals of *L. lithophaga* in 2011 exceeded the permissible limit published in the Turkish Food Codex for Pb, and closely approached the limit for Zn.

Kucuksezgin *et al*. (2014) evaluated the arsenic compounds in marine biota from Izmir Bay (Eastern Aegean) and found that inorganic arsenic occurred as a minor fraction. Fish and mussel samples were taken from different regions of Izmir Bay between 2009 and 2011. The highest concentrations of arsenic were found in Gediz site. The results revealed that estimated daily intakes of arsenic via consumption of flesh fish and shell fish were below the $BMDL_{0.5}$ values established by FAO/WHO.

Concentrations of a wide set of elements (As, Ba, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, Sr, U, V and Zn) in 26 dominant macroalgae from the Gulf of Thessaloniki, Aegean Sea were determined and compared by Malea and Kevrekidis (2014).

Gonul and Kucuksezgin (2007) evaluated the total mercury (THg) and MeHg concentrations in two fish species, *M. barbatus* and *D. annularis*, collected from different sites of Izmir Bay. Among the two species examined, the highest levels of total mercury, ranging from 23.1 to 221.4 $\mu g\ kg^{-1}$ wet wt, were determined in *D. annularis*. Total mercury concentrations ranged from 4.4 to 157.9 $\mu g\ kg^{-1}$ wet wt in *M. barbatus*.

Kontas (2006) determined the levels of mercury in suspended particulate matter, sediment, plankton and fish in Izmir Bay. Plankton, sediment Hg concentrations increased from outer bay to middle-inner bays. The maximum permissible mercury limit accepted by WHO for edible parts of marine organisms are 0.5 $\mu g\ g^{-1}$ (w w); results indicated that *M. merlangus* and *P. erythrinus* exceed this limit.

Parlak *et al*. (1991) evaluated heavy metal levels in some organisms collected from Lake Kuş (Bandırma). Besides, Uysal and Parlak (1992) assessed the concentrations of some heavy metals in *S. Serratum* (Leach) collected from İzmir Bay. Furthermore, Türkoğlu and Parlak (1999) investigated the levels of Cr in some organisms such as *S. vulgaris*, *B. luteum*, *A. laterna*, *G. niger* obtained from Izmir Bay. Cr concentration in the tissues of *S. vulgaris, B. luteum, A. laterna* and *G. niger* ranged between 128 and 663, 157 and 1022, 177 and 1215, 132 and 1493 $\mu g\ kg^{-1}$ wet wt., respectively.

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STATUS OF ORGANIC POLLUTANTS IN THE AEGEAN SEA: ORGANOCHLORINE RESIDUES AND POLYCYCLIC AROMATIC HYDROCARBONS

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1. Introduction

Organochlorines (OCs), such as polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs), represent an important group of persistent organic compounds (POPs) that have caused worldwide concern as toxic environmental contaminants. They are strongly particle-associated in aquatic ecosystems due to their hydrophobic properties, and tend to accumulate in sediments (Binelli *et al.,* 2008). As a result, sediments are usually regarded as the ultimate sink for many classes of anthropogenic contaminants to the environment, and are one of the best media for the long-term monitoring of many POPs (Jaffe, 1991; Lamon *et al*., 2009).

Although their production, usage and disposal have been regulated or prohibited in most of the developed countries, OCPs are still used at present in many developing countries (Zhou *et al*., 2008). In many instances, derivates of DDT, including DDE, DDD have been detected in surface waters, in sediments and as suspended solids more than 25 years after DDT was prohibited (Hung and Thiemann, 2002). The production and usage of many chlorinated compounds such as dieldrin, aldrin, endrin, chlordane, DDT, BHC, lindane and heptachlor were completely banned in Turkey in the 1990s. However total pesticide usage in Turkey in 1995 was 37,000 ton, and this usage has shown a steady increase year by year (TCV, 1998).

PCBs are an industrial product; there are no known natural sources. Atmospheric depositions, runoff from the land, and food chain transport (Morrison *et al*., 2002; Davis *et al*., 2007) have been regarded as the major sources of PCBs in aquatic environments. Urban runoff from local watersheds is a particularly significant pathway for PCB entry into the rivers (Yang *et al*., 2009). Although the use of PCBs was banned in Turkey in 1995, the import of PCBs continued illegally until the 2000s.

Among hydrocarbons, PAHs are a wide spread class of environmental pollutants that are carcinogenic and mutagenic. Under this consideration, the United States Environmental Protection Agency (USEPA) classified 16 of them as priority pollutants (Magi *et al.,* 2002). Due to their hydrophobic nature, these compounds tend to sorb onto particulate phase, making marine sediment a repository of these compounds

(Karickhoff, 1984). Resuspension of sediment or bioturbation of sediment into the water column are believed to play a significant role in bioaccumulation of these compounds in the food. Considerable amounts of petroleum products are discharged into the marine environment through runoff, industrial and sewage effluents, storm water drains, shipping activities, spillage, etc. and natural oil seeps can also be important in some areas. Significant changes in hydrocarbon composition can occur due to selective dissolution, evaporation, chemical and photo-oxidation and biodegradation. Short chain alkanes and simple aromatics are rapidly lost, but complex cyclic molecules such as steranes and hopanes are rarely affected (Volkman *et al*., 1992).

2. Organic pollutants in sediment and seawater

2.1 Pesticides in sediment and seawater

OCPs and PCBs were evaluated in sediments collected from the Eastern Aegean coast (Meriç River Estuary, Dardanelles Strait entrance, Edremit, Dikili, Candarli, Izmir (Outer, Middle, Inner), Kuşadasi Bays, Menderes Region, Akbük, Gökova, Datça, Marmaris Bays) in 2008 by Kucuksezgin and Gonul (2012). Total concentrations of total OCPs and PCBs in sediments ranged from bdl to 17.8 and bdl to 26.1 ng g^{-1} dwt, respectively. The results indicated that DDTs were the predominant contaminant in sediments. p,p'-DDE was the most often found OCP at all stations except Dardanelles Strait entrance. OCPs and PCBs were present in noticeably higher concentrations at Izmir Inner Bay than the other sites. According to established sediment quality guidelines (SQG), DDTs at four sites (Izmir Inner Bay, Çandarli Gulf, Edremit Bay and Menderes Region) and heptachlor at two sites (Meriç River Delta and Edremit Bay) would be more concerned for the ecotoxicological risk. The total PCB concentrations of the sediment samples did not exceed the ERM or PEL values, however PCB concentrations in Çandarli and Izmir Inner Bay above the ERL and TEL values.

The residual levels of OCPs and PCBs were determined in surface sediments collected from Izmir Bay were presented in Pazı *et al*., (2011). The concentrations of total OCPs ranged from 0.12 to 11.35 ng g^{-1} dry weight (dry wt) and were considerably higher in the Inner Bay and Gediz River estuarine sediments compared to the other stations (Figure 1 and Figure 3).

Relatively higher ΣDDT concentrations in the Gediz River estuary indicated DDT usage. Total PCBs varied from 0.3 to 44 ng g^{-1}. The highest values were found near the harbour. The potential sources of PCBs are due in part to equipment/utilities still in use such as old transformers and capacitors, to waste incineration and atmospheric deposition. Odabasi *et al*. (2008) showed that PCBs input was dominated by dry deposition due to atmospheric input in the entire Bay. In summary, the contamination of sediments in Izmir Bay by OCPs and PCBs appeared to relatively low by global standards and only sediments receiving the impact from Gediz River and Izmir Inner Bay approached the SQG.

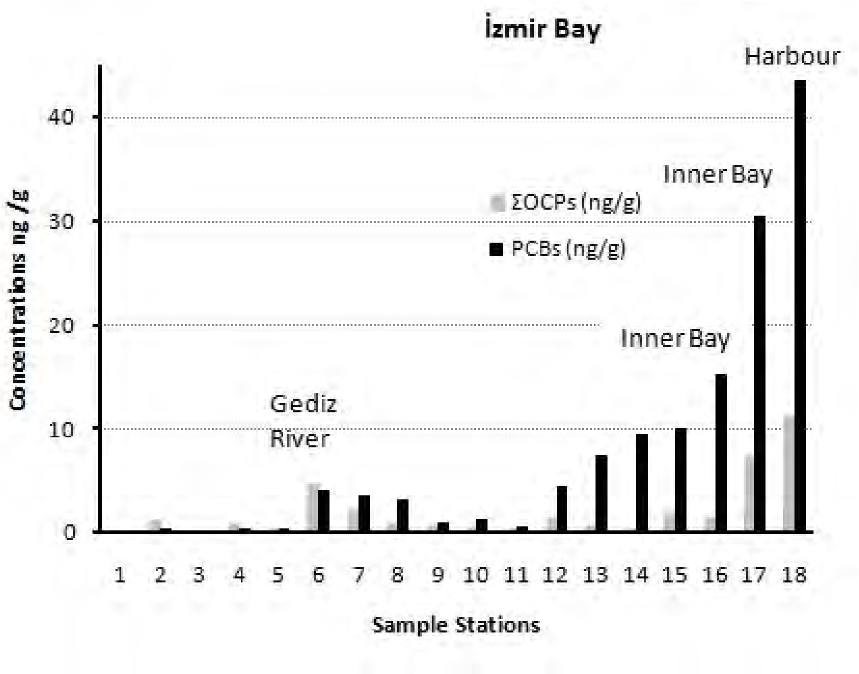


Figure 1. Total concentrations of OCPs, PCBs in the Izmir Bay (from Pazi *et al.,* 2011)

Levels of contamination of various chlorinated organic compounds in sediments from the Çandarli Bay were presented in Pazı *et al*. (2012). Concentrations of OCPs (sum of DDTs, HCB, lindane, heptachlor, aldrin, dieldrin, endrin) in surface sediments ranged from 10.2 to 57.3 ng g^{-1} (dry wt). The highest value was found at the station close to the Bakirçay Estuary, while the lowest value of OCPs occurred in the middle part of the Bay, corresponding to the lowest content of TOC. The results indicated that the DDTs, were the predominant contaminant in sediments of the Çandarli, were derived from the aged and weathered agricultural soils. Highest concentrations of PCBs were found in samples collected near the petrochemical industry (Figure 2, Figure 3).

Based on the SQG, the total PCB concentrations (3-205 ng g^{-1} dry wt) did not exceed the ERM or PEL values, with the exception of station near the petrochemical industry. The results indicate that adverse biological effects associated with the DDTs and PCBs levels at most of the studied sites in Çandarli could potentially cause acute biological impairment. The contamination levels of ∑DDT and ∑PCBs Çandarli were higher (4-6 fold) than those in the marine surface sediments from Izmir Bay (Pazi *et al*., 2011).

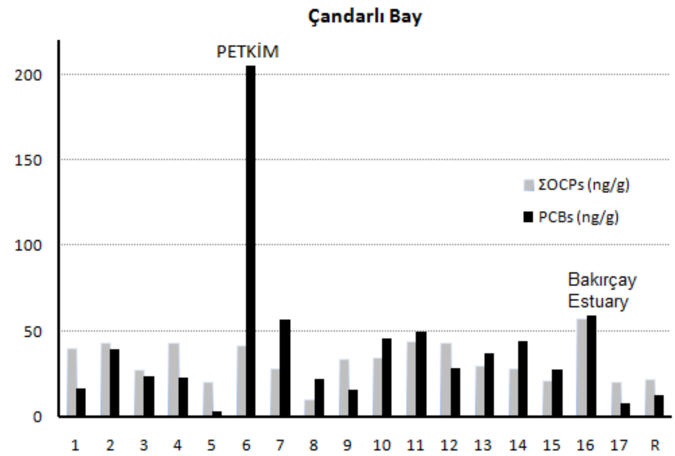


Figure 2. Total concentrations of OCPs, PCBs in the Çandarlı Gulf (from Pazı *et al.*, 2012)

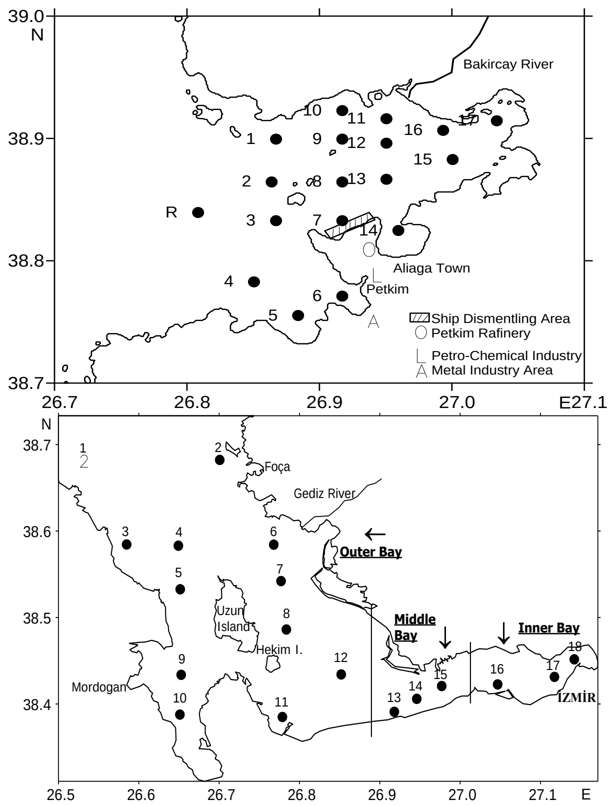


Figure 3. Station locations in Izmir Bay and Çandarlı Gulf

Persistent toxic substances (PTS) pose a hazard for ecosystems and human health as they undergo long-range atmospheric transport. Near-ground air and surface seawater concentrations of PTS were determined in 2012 in the Aegean Sea based on passive air and water sampling (Lammel *et al*., 2015). The direction of air–sea exchange was determined for 18 PTS. HCB, HCHs as well as DDT and its degradation products are evenly distributed in the air of the whole region. Air and seawater concentrations of DDT and their metabolites were elevated in Thermaikos Gulf, NW Aegean Sea. The PCB congener pattern in air is identical throughout the region, while polybrominated diphenylether (PBDE) patterns are obviously dissimilar between Greece and Turkey. Various pollutants, PAHs, PCBs, DDE, and penta- and HCB are found close to phase equilibrium or net-volatilisational (upward flux), similarly at a remote site (on Crete) and in the more polluted Thermaikos Gulf. The results suggest that effective passive air sampling volumes may not be representative across sites when PAHs significantly partitioning to the particulate phase are included.

Berrojalbiz *et al.* (2011) reported the results obtained during two east-west sampling cruises in June 2006 and May 2007 from Barcelona to Istanbul and Alexandria, respectively, where water and plankton samples were collected simultaneously. Both matrixes were analysed for HCHs, HCB, and 41 PCB congeners. The comparison of the measured HCB and HCHs concentrations with previously reported dissolved phase concentrations suggests a temporal decline in their concentrations since the 1990s. On the contrary, PCB seawater concentrations did not exhibit such a decline, but show a significant spatial variability in dissolved concentrations with lower levels in the open Western and South Eastern Mediterranean, and higher concentrations in the Black, Marmara, and Aegean Seas and Sicilian Strait. PCB and OCPs concentrations in plankton were higher at lower plankton biomass, but the intensity of this trend depended on the compound hydrophobicity. For the more persistent PCBs and HCB, the observed dependence of POP concentrations in plankton versus biomass can be explained by interactions between air water exchange, particle settling, and/or bioaccumulation processes, whereas degradation processes occurring in the photic zone drive the trends shown by the more labile HCHs. The presented results provide clear evidence of the important physical and biogeochemical controls on POPs in the marine environment.

2.2 PAHs in sediment and seawater

Aliphatic and polycyclic aromatic hydrocarbons (PAHs) were determined in surficial sediments from the Aegean Sea in the Eastern Mediterranean in 2008 (Gonul and Kucuksezgin, 2011). Total aliphatic hydrocarbons (n-C12 to n-C35) ranged from 330 to 2660 ng g^{-1} dry wt, while 19 PAHs varied between 73.5 and 2170 ng g^{-1} dry wt (Figure 4).

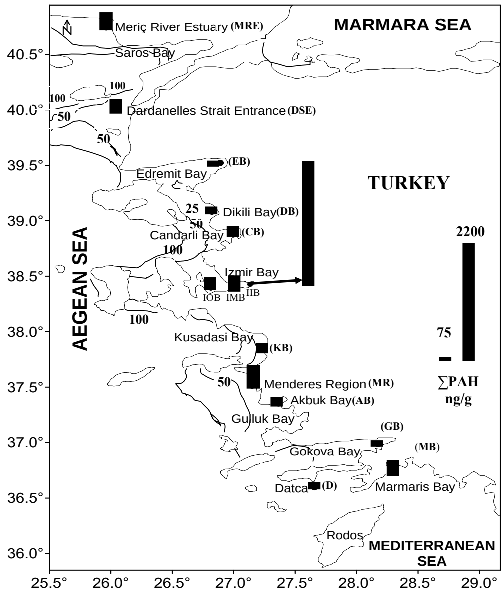


Figure 4. Distribution of total PAH concentrations along the Eastern Aegean coasts (from Gonul and Kucuksezgin, 2012)

Total concentrations of both aliphatic hydrocarbons and PAHs ranged from a relatively low to a moderate PAHs pollution compared to other urbanized coastal areas worldwide. The spatial distributions of aliphatic hydrocarbons and PAHs indicated that urban runoff and transport from the continental shelf is the major input pathway of anthropogenic and biogenic hydrocarbons from terrestrial sources in the near-shore area.

PAH levels at all sites were below the effects range-low (ERL) and effects range median (ERM) values except fluorene. The average and maximum fluorene concentrations exceeded ERL, but below ERM, in the Izmir Inner Bay. Meanwhile, the concentration levels of naphthalene, fluorene, phenanthrene, fluoranthene, pyrene, benzo[a]anthracene, and chrysene were higher than threshold effect level at the same site, but all these compounds were significantly lower than the probable effect level. The results indicated that the sediments should have potential biological impact.

The concentrations of the 5 aliphatic (n-tetradecane, n-heptadecane, pristane, n-octadecane, and phytane) and 16 aromatic hydrocarbons of concern to USEPA detected in sediments of Izmir Bay ranged from 84 to 4427 and 2.5 to 113 ng g^{-1} dwt (Darilmaz and Kucuksezgin 2007). The concentrations of 5 aliphatics found in sediment samples from the Izmir Bay were generally less than 1 µg g^{-1} dwt, except for samples collected from the Inner Bay stations. Aliphatic hydrocarbon concentrations in the Inner Bay were higher than those in the Crete, eastern Mediterranean area (Gogou *et al.*, 2000), and similar to those analysed in the Black Sea and Bosphorus (Readman *et al*., 2002). The PAH levels found in samples reviewed in the present study were consistent with those reported for open sea sediments of the Aegean Sea, Kavala Bay, Black Sea coastline, and northwestern Black Sea (Maldonado *et al*., 1999; Gogou *et al*., 2000; Readman *et al*., 2002; Papadopoulou and Samara, 2002).

Aliphatics and PAHs were determined in sediments from the Çandarlı Gulf in 2009 by Kucuksezgin *et al*. (2012). Aliphatics ranged from 3.88 to 24.7 ng g^{-1} while aromatics varied between <4.15 and 405 ng g^{-1} (dry wt). 16 PAHs concern to USEPA ranged from a relatively low to a moderate PAHs pollution compared to other urbanized coastal areas worldwide. 3- ring PAHs were most abundant in the sampling area. Both pyrolytic and petrogenic PAHs were present in most samples, although petroleum derived PAHs were dominant at the stations situated near the refinery and petrochemical, metal industry and pyrolytic sources were mainly prevalent in the estuary of Bakırçay River. The ratio of UCM (Unresolved Complex Mixture) to n-alkanes and CPI values in station near the PETKIM industry indicate that the main contribution to petroleum hydrocarbon contamination is via oil and its products. PAH levels at all sites were below the ERL and ERM except fluorene. The results indicated that the sediments should have no potential biological impact except stations located in the vicinity of near the PETKIM petrochemical industry.

PAHs and aliphatic hydrocarbons in sediment of the Aliağa Bay were investigated to evaluate an environmental risk assessment from PAHs contamination in 2009–2010 (Neşer *et al*., 2012). Aliağa Bay is one of the most important maritime zones of Turkey where shipping activity, shipbreaking industry, steel works and petrochemical complexes exist together. Total PAHs concentrations ranged from 0.07 to 20.9 µg g^{-1} (dry wt). Aliphatic and PAHs diagnostic ratios showed to be mainly petroleum-originated and pyrolitic contaminations, respectively. The TEL/PEL analysis suggests that Aliağa sediments were likely to be contaminated by acutely toxic PAH compounds.

Marine sediment contamination was evaluated in a set of sediment specimens collected from Izmir Bay (Turkey) and Mytilene Harbour (Greece) in the Aegean Sea (Kostopoulou *et al*., 2013). Sediment samples from Izmir and Mytilene were analyzed for metals and seven PAHs. The sum of PAHs near harbour in Izmir displayed significantly higher levels than Mytilene sediment. The results point to higher pollution status in Izmir Bay, especially most sampling sites in the inner bay, compared to Mytilene Harbour, detected as metals and PAH contamination.

Aliphatic and polyromantic hydrocarbons were determined in surficial sediments from the Cretan Sea (South Aegean Sea) by Gogou *et al.* (2000). Total concentrations of both aliphatic and PAHs were low (562–5697 and 14.6–158.5 ng g^{-1}, respectively) with respect to other coastal sediments worldwide and compare with concentrations found in open sea areas. The composition of aliphatic hydrocarbon was dominated by UCM indicating the presence of petroleum-related hydrocarbon inputs as confirmed by the detection of specific a, b-hopanes. PAH consisted mainly of pyrolytic four- to five-ring compounds. UCM and PAH amounts revealed that Cretan Sea receives low supply of anthropogenic material compared to NW Mediterranean. The spatial distribution of aliphatic and PAH indicated that urban run-off and transport from the continental self are the major input pathway of anthropogenic and biogenic hydrocarbons from terrestrial sources in the near shore area, whereas atmospheric transport might be the significant source of hydrocarbons in the deep area.

Botsou and Hatzianestis (2012) measured the levels of PAHs in sediment samples at the Hellenic coastline in Greece, and investigated their sources and evaluated their potential toxicity based on SQG. The levels of PAHs were found to vary widely from 100 to more than 26000 ng g^{-1}. The highest levels were found in the close vicinity of an alumina production plant in the Gulf of Corinth. High levels of PAHs were also found at a few sites in each of the areas studied, close to a nickel production plant (North Evoikos Gulf), at the rainwater and wastewater outfalls of the great urban areas of Athens and Thessaloniki and at the industrialized area of Elefsis Bay (Saronikos Gulf). At the most contaminated sites PAH had a pyrolytic origin. Comparison of PAH levels to the SQG indicated that less than 15% of the sites studied have an intermediate probability (24–49%) of being toxic. In general, discrete point sources were identified as the major contributors of PAH contamination in the Hellenic coastal zone.

Kucuksezgin *et al.* (1995) investigated the distribution and transportation of dissolved and dispersed petroleum hydrocarbon levels in open sea and coastal stations of the Aegean Sea with the hydrodynamics of the water masses of the region. It is clear that distribution of this pollutant is strongly affected by physical dynamics of environment. The data were collected during cruises in November 1994, in the framework of National Marine Measurement and Monitoring Programme in the Aegean Sea. In the present study additionally the Chlorophyll-a was measured fluorometrically and there is good correlation between petroleum hydrocarbon and chlorophyll-a in the Aegean Sea. DDPH data was used to search origin of hydrocarbons: biogenic or non biogenic.

Oil pollution in the surface water of the Aegean Sea was investigated from the Çanakkale Strait to the Marmaris Harbour in 2005 (Ozturk *et al.,* 2006). The oil concentrations in water ranged from 6.2 at Datca to 60 µg l^{-1} at Kuşadası through Russian crude oil equivalent. The highest polluted areas were Babakale-Kuşadası Bay, West of Giadoros Island and Yalıkavak-Kardak Island. The comparison the results of present study with the earlier findings showed that the pollution level increased during the years in this area.

Ozturk *et al*. (2007) investigated the oil pollution of the southern Aegean and Mediterranean Sea from the Bozburun Peninsula to Iskenderun Bay in 2006. The highest carbon concentration was determined by UVF using Iraq crude oil and also chrysene as references materials. The petroleum hydrocarbon levels in sea water were 4.2 µg l^{-1} in Antalya Bay and 100 µg l^{-1} in Iskenderun. The highest polluted areas are Iskenderun, Bozburun and Kalkan.

Oil pollution of the Aegean Sea was investigated at 13 stations in August 2007 and 11 stations in August 2008 (Balcıoglu *et al*., 2010). The oil level was calculated using references as Iraq crude oil and chrysene. The highest level was found as 94 µg l^{-1} at the entrance of Çanakkale Straight in 2008. A comparison of the present results with data obtained earlier in the same region the oil pollution level increased during the years.

Guven *et al.* (2008) investigated oil and detergent concentrations in 2005 and 2006 in sea water and sediment near the refinery of TUPRAŞ and Aliağa, Istanbul Strait, Golden Hom and Çanakkale Strait. The highest values were found in refinery areas. The oil concentrations in sea water were found as 30 for Istanbul Strait, 4214 for Golden Hom, 43 for Çanakkale Strait, 90 for TUPRAŞ 3, 7 µgl^{-1} for Aliağa. In sediment, 9573 for Istanbul Strait, 1126 for Golden Horn, 32 for Çanakkale Strait, 1501 for TUPRAŞ, 59 µg g^{-1} for Aliağa. These oil levels found are higher than the limit values for sea water and sediment.

3. POPs and PAHs in biota

PTS appear in most urbanized coastal areas of the world. Like many other countries, Turkey is also facing problems concerning pesticides and other PTS residues (Kolankaya, 2006). According to sampling between 1979 to 1980 PCBs were not detected in *M. barbatus* living in the Aegean Sea, and its derivatives were detected in low levels (Kucuksezgin *et al*., 2001).

The distribution of PAHs was investigated in red mullet (*Mullus barbatus*) and sediment samples in the eastern Aegean Sea by Kucuksezgin *et al*. (1999). The data were collected during cruises in July and November 1994, in the framework of National Marine Measurement and Monitoring Programme in the Aegean Sea. PAHs were detected in the tissue of *Mullus barbatus* from nine sampling sites throughout the study area ranging from 0.03 to 0.46 ug/g (fresh weight).

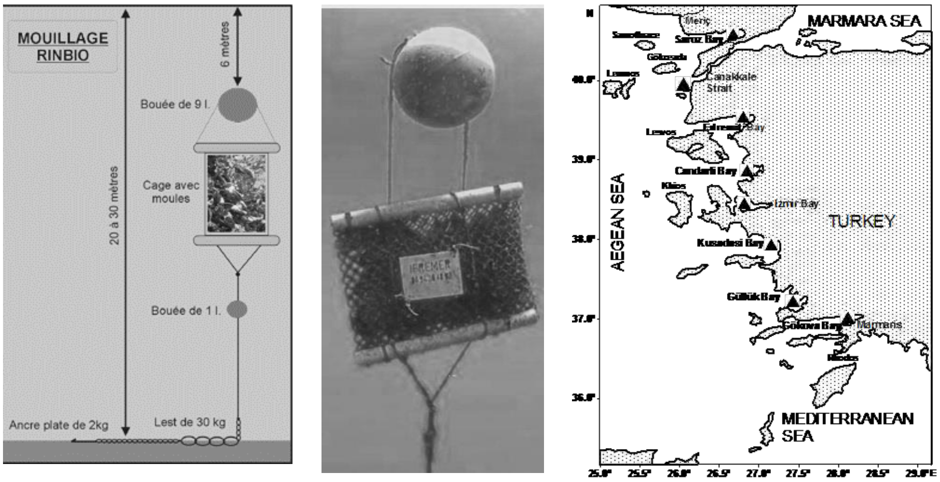
The OCP residues were analysed in water, sediment, plankton, crab, and fish samples collected during the field surveys in the Köyceğiz Lagoon System which is a specially protected area (SPA) between 1992 to 1994 (Çalışkan and Yerli, 2000). No OCP residues were detected in water and plankton samples. Residues of OCPs were analysed in *Callinectes sapidus* (blue crab) and in fish (*Capoeta capoeta, Oreochromis mossambica, Liza ramada, Chelon labrosus and Anguilla anguilla*). Residues of 5 organochlorine pesticides (α-HCH; 0.48 μg kg^{-1}, β-HCH; 0.58 μg kg^{-1}, γ -HCH; 2.60 μg kg^{-1}, aldrin; 0.42 μg kg^{-1}, and endrin; 1.80 μg kg^{-1}) were found in crab samples, while 7 OC (Total DDT, dieldrin, α-HCH, β-HCH, γ -HCH, aldrin and endrin) were observed in fish samples. One of them, α-HCH was found in all fish species' muscle tissues. The average of results were 6.75 μg kg^{-1} for C. capoeta; 35.90 μg kg^{-1} for *O. mossambica*; 26.30 μg kg^{-1} for *L. ramada*; 5.33 μg kg^{-1} for μg kg^{-1} for *C. labrosus*; 5.00 μg kg^{-1} for *A. Anguilla.* The OC residue level is lower in blue crab tissue than in fish tissue.

OCPs (aldrin, alpha-endosulfan, beta-endosulfan, 2,4'-DDT, and 4,4'-DDE) and PCBs (PCB28 and PCB52) were screened in fish culture cages off the Aegean Coast of Turkey (Koç *et al*., 2008). Sea bass *(Dicentrarchus labrax*) and sea bream (*Sparus aurata*) were randomly selected from three coastal areas in 2004. Samples of 114 fish were analysed by gas chromatography (GC). No residues exceeding limits established by the European Union Directive were detected. However, 4,4'-DDE was found in 2.63% of the samples. The amounts of residues in all positive samples were lower than the maximum tolerance limits (0.2-1 mg kg-1) accepted by the EU Directive. Contamination levels varied with species, ranging 18-200 ng ng^{-1} wet weight. Other chemicals were not detected in fish samples.

Mytilus galloprovincialis are filter feeders and were often used to monitor PAHs contamination in the marine environment. Kasiotis *et al*. (2015) was implemented in the frames of a bilateral funded project between Greece and Turkey entitled "Pollution monitoring of the Northern Aegean coast by use of transplanted mussels: determination of priority pollutants and their levels and development of suitable biomarkers". Pristine Turkish sites with minimum effect from anthropogenic activities, in contrast with Greek sites which were subjected to heavy industrial and shipping activity, were selected. A gas chromatographic tandem mass spectrometric method (GC-MS/MS) was developed and validated to monitor 34 compounds (16 EPA priority PAHs and 18 OCs). Analyses of mussel samples in 2011 from sites with the limited anthropogenic pollution shores have shown the occurrence of 11 pollutants (6 PAHs, 5 OCs), while in the samples from sites with intensive activity and expected pollution, 12 PAHs and 6 OCs were detected. Biochemical and biological responses studied only in mussel samples from the sites with the highest contamination showed a situation that was under strong seasonal influence. The intensity of the response was also influenced by deployment duration. Noteworthy correlations were detected among biochemical/biological effects and between mussel body burden and these effects.

The MYTITURK project allows to try classification of the contaminant levels in the Eastern Aegean coast in transplanted mussels kept at sea in eight different bays

(Saros Bay, Çanakkale Strait, Edremit, Çandarlı, Izmir, Kuşadası, Güllük, Gökova Bays) for 3 month periods in 2011 (Kucuksezgin *et al.,* 2013). In this study; 17 PAHS, 9 OCPs were evaluated in coasts using *M. galloprovincialis* (Figure 5).



(IFREMER, 2014) (IFREMER, 2014)

Figure 5. Mussel cages and location of stations on the Aegean coasts

OCPs and PCBs were found in all samples (6.1–9.9 ng g^{-1}, 5.6- 39.9 ng g^{-1}, respectively). PCBs concentrations were higher in transplanted mussels from Çanakkale Strait Outlet due to industrial activities was originated from Marmara Sea. DDE/DDT ratio in the caged mussels form Güllük and Gökova Bays indicated recent DDT usage in these areas. It is possible to identify low contamination level in the coasts considering PAH contamination (29.4 and 46.5 ng g^{-1}). Molecular indices indicated that PAH pollution was the result of pyrolitic inputs. Mussel transplantation procedure adopted the Eastern Aegean coasts is a useful tool for environment active biomonitoring. According to levels of POPs in mussel no risk was observed for public health.

Concentrations of PAHs, PCBs and OCPs in sediments and mussels (caged and/or native) were determined at 16 stations in six major sites of coastal Turkey in 2012 (Okay *et al*., 2014). The study area consists of six major sites of coastal Turkey, namely, Saros Bay (northeastern Aegean Sea), Çanakkale Strait, Tuzla shipyard area (İstanbul, Marmara Sea), Aliağa ship breaking area (Aliağa Bay Aegean Sea), Marina 1 (Güllük Bay) and Marina 2 (Marmara Sea). The total PAH concentrations in the sediments varied between nd and 79.674 ng $g^{−1}$ dw, while the total OCP concentrations were in the range of nd to 53.7 ng $g^{−1}$ dw. The total PAH concentrations in mussels varied between 22.3 and 37.4 ng $g^{−1}$ ww. The average concentrations of total PCBs in mussels were 2795 pg $g^{−1}$ ww in the shipyard, 797 pg $g^{−1}$ ww in Marina 2 and 53 pg $g^{−1}$ ww in Marina 1 stations. The micro-organic contaminant profile patterns, toxicity tests and biomarker studies showed that shipyards and shipbreaking yards are the major potential sources of organic pollution in coastal areas.

Polycyclic aromatic and aliphatic hydrocarbons were analyzed in red mullet and annular sea bream from the Izmir Bay (Darilmaz and Kucuksezgin, 2012) in 2000–2001 and 2004–2005 periods at five locations. Red mullet showed higher PAHs (202 -556 ng g^{-1} dw) and aliphatics than annular sea bream (78.7 to 415 ng g^{-1} dw). Molecular ratios showed pyrolitic inputs for PAHs, biogenic and anthropogenic inputs for aliphatics. The carcinogenic PAH, benzo(a)pyrene, was detected in most fish samples in levels ranged between 22.2 and 64.1 ng g^{-1} dw. The average PAH contamination level was within the ‘‘moderate’’ category in fish from Izmir Bay.

The concentrations of 22 PAHs in *Posidonia oceanica* seagrass, sediments, and seawater from the Alexandroupolis Gulf in the Aegean Sea, were investigated from 2007 to 2011 (Apostolopoulou *et al.,* 2014). Temporal trends of total PAH contents in *P. oceanica* and sediments were similar. PAH levels in seawater, sediments, and seagrasses generally decreased with increasing distance from Port. Leaves and sheaths of *P. oceanica* had higher PAH levels than roots and rhizomes. *P. oceanica* accumulates PAHs and has good potential as a bioindicator of spatiotemporal pollution trends. PAH concentrations were also examined using in situ passive seawater sampling and were compared to results of passive sampling in the laboratory using local sediments and seawater. Levels of high molecular weight PAHs assessed using passive samplers confirmed the decreasing gradient of pollution away from Alexandroupolis Port.

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ORGANOTIN COMPOUNDS POLLUTION IN SEDIMENT SAMPLES ALONG THE TURKISH AEGEAN SEA COAST[#]

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1. Introduction

Organotin compounds (OTs) are organometals characterized by a tin (Sn) atom covalently bound to one or more organic substituents (e.g.. methyl. ethyl. butyl. propyl. phenyl. octyl) (Hoch, 2001). According to the number of organic groups organotins can be classified in four distinct classes: monoorganotins ($RSnX_3$), diorganotins (R_2SnX_2), triorganotins (R_3SnX) and tetraorganotins (R_4Sn). TBT has identified as an endocrine disruptor, responsible for imposex syndrome in certain marine gastropods at concentrations in water of a few ng/L. The number and nature of the organic group attached to tin plays an important role in the toxicity (Sousa *et al*., 2014).

Organotin compounds (OTCs) have been presented into the environment primarily as a result of human activity. The first organotin compound produced in a laboratory by Frankland in 1849. Research intensified with the development of industrial applications for organotin and since then OTCs have been used in applications including antifouling paints. PVC stabilisers, timber treatment, and biocidal products (Fent 1990).

Tributyltin (TBT) is one of the most toxic compounds introduced into the environment among the organotin. Tributyltin was largely introduced in the natural environment as an anti-fouling agent in paints for the hulls of ships and other structures to be used in the marine environment.

Tributyltin was accredited as the ideal antifouling agent firstly for its effectiveness and long duration; and secondly belief that environmental friendly nature by easily degraded by UV light and microorganisms in the aquatic environment (Sousa *et al*., 2014). However, this belief confronted with hard facts dramatically.

[#] *This article has been dedicated to Asst. Prof. F. Sanem Sunlu (R.I.P) (1968-2011) who is my beloved wife and also my better half.”*

Despite widespread restrictions and bans on its use the TBT remains a problem as an aquatic contaminant in most countries. High levels of these compounds and its degradation products are still posing a risk in water, sediments and sewage sludge. This chapter aims to gather information about the chemistry, environmental fate and levels of organotin compounds in the sediments along the east coast of Aegean Sea.

1.1 Sources and pathways of organotin compounds in the environment

Organotin compounds are released through several routes into the environment. The major input of triorganotin compounds into aquatic systems derives from their use in anti-fouling paints on any submersed structures. Other important routes include the runoff from agriculture fields; the discharge of contaminated effluents, the deposition of sewage sludge and the leachates from landfills (Figure 3) (Sousa *et al*., 2014). Harbor areas are specially affected by TBT contamination. In harbor sediments, flakes of removed paints from vessels and discharged paint wastes may be present and may serve as reservoirs that cause locally high concentrations of TBT (Carvalho *et al*., 2010). Hence, special attention is given to polluted sediments since they are likely to be responsible for the TBT content of the overlying water.

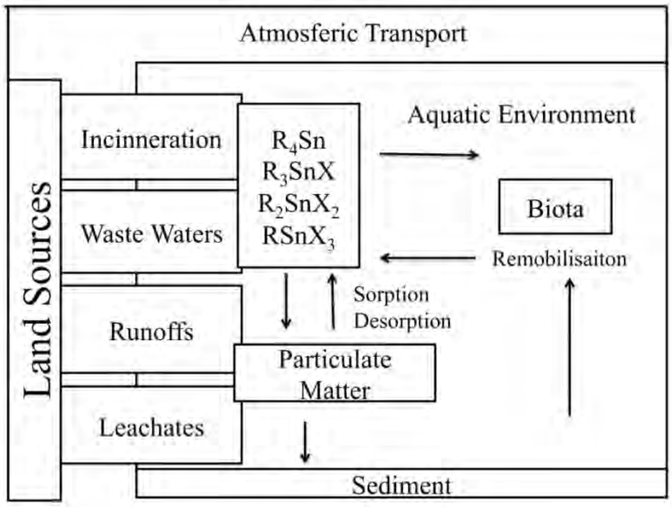

Figure 1. Schematic representation of the main sources and pathways of organotin compounds in the environment (Adapted from Sousa *et al*., 2014)

1.2 Environmental fate of organotin compounds in the marine water and sediment

When TBT enters the marine environment distribution of its species is influenced by factors such as the species and population density of aquatic organisms, dissolved and suspended organic material, pH, salinity, temperature and solubility in water (Fent, 1990). Most of it is believed to be adsorbed on the sediment, due to the high affinity of TBT to sediment particles (Al-rashdi, 2011).

Several factors can influence the degradation rate of organic tin compounds into inorganic tin namely: temperature, light intensity, pH, salinity and the nature and density of microbial communities (Hoch, 2001). Investigations of the degradation rate of TBT in the marine environment demonstrated that half-lives of TBT are several days to weeks in water, and from 1 to 10 years in sediment (Hwang *et al*., 2004). However, tributyltin may become bioavailable again as a consequence of its resuspension, diffusion into the water column and/or decomposition (Hoch, 2001; Diez *et al*., 2002).

Thus TBT can accumulate in these sediments, leading to a persistent ecotoxicological risk (Alzieu *et al*., 1986). While the degradation of TBT in water happens due to photlysis and biological process, only biological degradation occurs in the sediment (Heroult *et al*., 2008). The ability of marine sediments to accumulate these compounds varies geographically and geologically, according to the physicochemical characteristics of the sediment (e.g. particle size, org. C content) (Carvalho *et al*., 2009).

1.3 Chemical analysis

Determination of organotin compounds mainly involve four steps: extraction, production of volatile derivatives, separation, and detection. Different extraction techniques have been used for organotin analysis. Derivatization methods include formation of alkyl derivatives using a Grignard reagent, formation of ethyl derivatives using sodium tetraethylborate, or formation of hydrides using sodium tetrahydroborate (Al-rashdi, 2011). Derivatized organotin are generally separated mainly by gas chromatogaraphy besides high-performance liquid chromatography (HPLC), capillary electrophoresis (CE) and supercritical fluid chromatography (SFC). Separeted compounds detected by the selective techniques such as, atomic absorption spectrometry, flame photometric detector, or pulsed flame photometric detector (Carvalho *et al*., 2010).

1.4 Adverse effects and regulation

The biological activity of organotin compounds is mainly determined by the number and nature of organic groups linked to the central tin atom; the activity decreases in the following order: (tri) R_3 SnX > (di) R_2 SnX_2 > (mono) $RSnX_3$ (Pellerito and Naggy, 2002).

Although OTCs achieve their intended goals quite effectively, they have also high environmental persistence and the ability to transfer along the trophic chains

(Carvalho *et al*., 2010). The most common toxicological consequences of TBT are the disruption of the endocrine system of marine shellfish, leading to the development of male characteristics in female species (imposex) (Alzieu *et al*., 1986). Impairment of the immune system of organisms, which develop shell malformations, reduced reproduction and growth retardation of some marine organisms causing a drop in the population of these species (Sarradin *et al*., 1991). The toxic effect of TBT appears in water and sediments at very low concentrations (1-2 ng/L) (Hoch, 2001).

Organotin compounds can also enter the food chain by accumulation in different marine species and plants destined for human consumption such as oysters, farmed salmon, mussels, clams, snails and seaweed (Carvalho *et al.,* 2010).

These facts forced the development of national legislations all over the world. The use of antifouling paints containing TBT has been banned on vessels under 25m in France since 1982, in England since 1987 and in the United States since 1989. More recently, International Maritime Organization (IMO) banned the use of TBT-based paint products on ships from 1 January 2003 by AFS Convention (International Convention on the Control of Harmful Anti-fouling Systems on Ships) (Champ, 2003). By the beginning of 2008, the presence of such paints on ships had to be completely removed or covered (Champ, 2001).

Despite widespread restrictions and the strict bans on its use, significant concentrations of this compound and its degradation products, dibutyltin (DBT) and monobutyltin (MBT), are still found in water, sediments and sewage sludge (Arnold *et al*., 1998).

Increased awareness of the impacts resulting from the use of toxic antifouling paints has prompted investment in the research and development of non-toxic alternatives such as silicone elastomers, waxes or silicone oils, and ‘‘natural’’ coatings that source antifouling compounds from algae and other marine organisms (Hellio *et al*., 2009), but replacement of TBT compounds by other paints is more expensive to utilize large scale.

2. Sampling area

The Aegean Sea, has the most intense maritime activities due to marine transportation involved in trade routes west of the Straits of the Mediterranean, Marmara and Black Sea because of the importance of open, natural beauty and the center of yachting tourism in coastal intricate structure of the housing in and around the many other ports, for host slipway and due to the availability of water for aquaculture.

Station 1, is located between 39° 19’ N latitude and 26° 41’ E longitude. Station 2 located in Aliağa coastal area which is around 1.5 km. long and has 26 ship wreckling facilities. In winter periods these facilities decompose ships less than in summer periods when a mean of 4-6 ships are decomposed per facility. Station 3 is located between 36º 50' 06" N–30º 06' 02" E latitude and longitude. Station 4 is located between 39° 42’ 25” N latitude and 27° 04’ 04” E longitude. Station 5 is a big hosting yacht and bonding area located between 38° 19’ 30” N latitude and 26° 20’ 42” E longitude. Station 6 and Station 7 are located at 37° 52’ 20” N–27° 15’ 46” E and 37° 02’ 00” N–27° 25’ 50” E latitudes and longitudes respectively (Figure2).

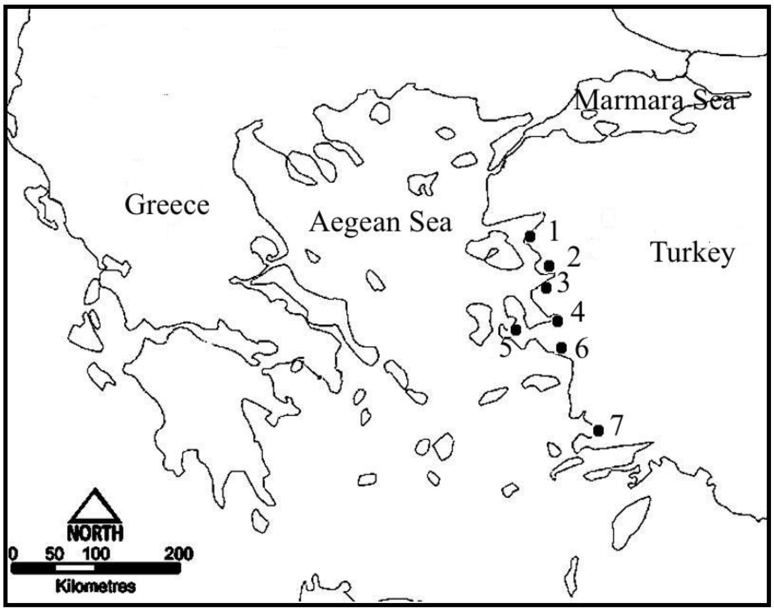

Figure 2. The map of sampling stations

3. Sampling and analysis

Sediment samples were collected from 7 stations ranging from northern stretch of Aegean Sea from Station 1 in southern stretch to Station 7 along the coastal zone between March 2009 and August 2009. Reference stations were determined which are relatively far from the maritime activity where human and marine environment entwined as in beaches and piers.

Sediment samples were collected by standard (6x6x6) stainless steel Ekman Grab. Sample analysis carried out GC/MS, HP Agilent 6890 coupled 5973 N Mass Selective Detector. Method for instrumental analyses are adopted from Centineo *et al*. (2007). Non-detected (nd) limits for MBT, DBT, TBT were 0.003, 0.001 and 0.001 ng

g^{-1} Sn respectively). In order to quality control of the analytical results CRM-462 (Coastal Sediment for Butyltins) provided from IRMM (Institute for Materials and Measurements) and analyses of CRM-462 proved that the method was able to accurately determine levels of OTC's.

4. Results and Discussion

As a result of the winter sampling, the highest ∑butyltin level was detected from Station 4 (1928 ng g^{-1} Sn). The lowest ∑butyltin level was measured from Station 3 (809 ng g^{-1} Sn) with a mean concentration of ∑butyltin for all stations being 1404 ng g^{-1} Sn. The highest concentration of ∑butyltin was detected in Station 1 (1464 ng g^{-1} Sn) and the lowest concentration was measured in the Station 3, 4 and 6 from the reference points (nd). A mean concentration of ∑butyltin for overall reference points was 570 ng g^{-1} Sn.

Table 1. Minimum and maximum OTC levels in sampling and reference stations after winter and summer period (ng g^{-1} Sn dw)

	WINTER		SUMMER	
Sampling Stations				
	Minimum	**Maximum**	**Minimum**	**Maximum**
MBT	nd	160.0	301,8	2598.9
DBT	410,0	928.4	598,2	1371.3
TBT	nd	1050.0	320,6	3008.6
Reference Stations				
MBT	nd	nd	nd	455.0
DBT	nd	900.8	nd	945.4
TBT	nd	563.2	nd	1262.4

Sampling station 2 is a place where retired ships wait for paint removal process on the ground by several firms causing an uncontrollable TBT contamination. The highest value of TBT (1050 ng g^{-1} Sn in winter and 3009 ng g^{-1} Sn in summer) (Table 1) confirmed the related risky situation in the aforementioned site. Furthermore reference station values were higher in summer than in winter because of the area being an open bay and anchored ships in the bay being much more in summer than in winter (in winter period no ships have been observed but in summer period 25 ships have been detected to be anchored). Every ship grounding process could lead to the transportation of remobilized TBT into water by mixing sediment (Hoch, 2001).

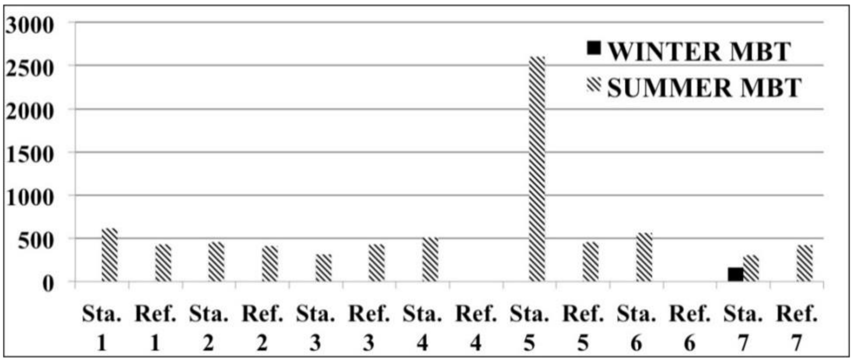

Figure 3. Winter and summer levels of MBT from the sampling stations (ng g^{-1} Sn dw)

Although 928 ng g^{-1} Sn DBT and 999 ng g^{-1} Sn TBT were measured in Station 4 (75 ship capacity) in winter sampling, 507 ng g^{-1} Sn MBT,1004 ng g^{-1} Sn DBT and 1225 ng g^{-1} Sn TBT were detected in summer sampling. The high TBT values in summer period may be consequent of launching ships into the sea especially in summer time and discharging scraped paints into sea without any treatment in spring. After winter sampling, all OTC values were below the detection limits. The difference between station and reference station may caused by position of Station 4 in the middle of the inner bay and by the adjacent İzmir Harbour and ferry port. The low levels of reference station in winter sampling may be caused by situation of reference station 4 near the mouth of the bay and thus by being away from the ferry traffic and water movements. In the summer sampling OTC levels were determined as 945 ng g^{-1} Sn DBT and 1262 ng g^{-1} Sn TBT in reference station 4 (Figures 3, 4 and 5).

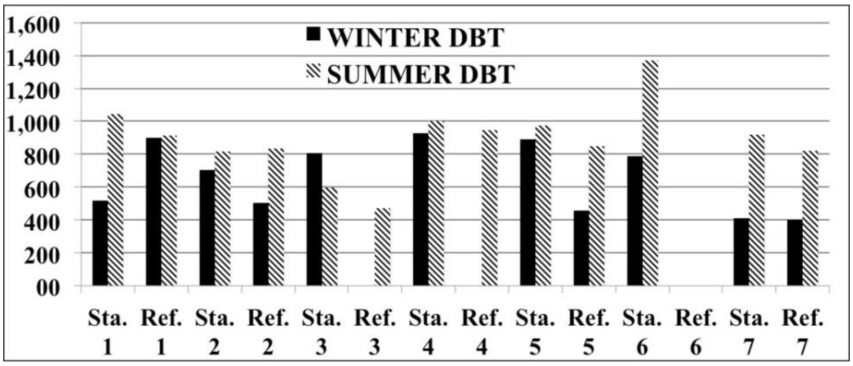

Figure 4. Winter and summer levels of DBT from the sampling stations (ng g^{-1} Sn dw)

After winter sampling OTC levels were 518.4 ng g^{-1} Sn DBT and 828 ng g^{-1} Sn TBT in Station 1 (240 boat capacity). Despite the high boat capacity, OTC levels in

Station 1 were lower than Station 4 due to the intensive marine traffic both in summer and winter periods in Izmir Bay. The levels were 620 ng g^{-1} Sn MBT, 1043 ng g^{-1} Sn DBT and 2200 ng g^{-1} Sn TBT after summer sampling, which may be induced by maximum usage of capacity in summer season. Painting activities in dock yard (100 boat capacity) in spring could also be a major source of contamination. Maximum release rate of biocid occur from the newly painted hulls (Hoch, 2001), which could explain the high accumulation levels in this site. 901 ng/g DBT and 563 ng g^{-1} Sn TBT were determined in reference station 1 after winter season. In summer period, while 425 ng g^{-1} Sn MBT and 915 ng g^{-1} Sn DBT were measured TBT was not detected (Figures 3, 4 and 5). The close structures of the bay and many harbours, boat yard and overwintering places located in the area may cause considerable levels of the compounds. TBT's undetectable levels in reference station in summer and occurance of MBT both in reference station and marina could suggest that TBT is degredated by bioactivity in the area.

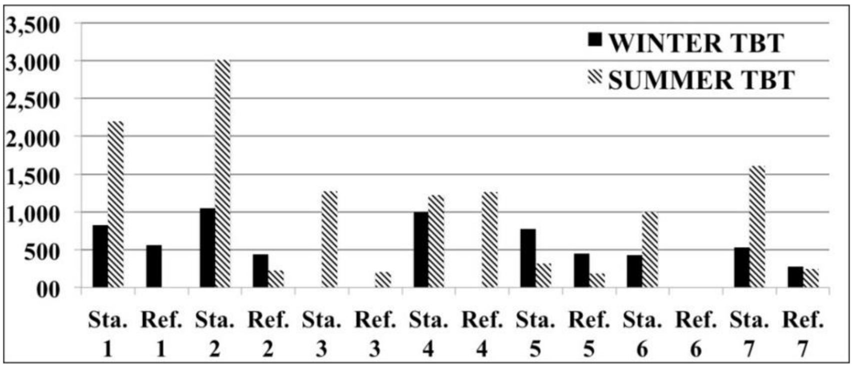

Figure 5. Winter and summer levels of TBT from the sampling stations (ng g^{-1} Sn dw)

892 ng g^{-1} Sn DBT and 778 ng g^{-1} Sn TBT were measured in Station 5 in winter period while 2599 ng g^{-1} Sn MBT, 977 ng g^{-1} Sn DBT and 321 ng g^{-1} Sn TBT were detected in summer season. The marina (180 boat capacity) was constructed as Turkey's first private marina in 1974. The marina has been maintained for a couple of times since its establishment and serves for the pleasure craft for the longest period of time in Turkey, which was quite likely to lead to accumulation of OTC's. The values were 455 ng g^{-1} Sn for DBT and 444 ng g^{-1} Sn for TBT in reference Station 5. In summer time 455 ng g^{-1} Sn MBT, 847 ng g^{-1} Sn DBT and 321 ng g^{-1} Sn TBT were determined. DBT concentrations were almost same as TBT concentrations may suggest that TBT has been broken by bioactivity (especially phytoplankton) in the area (Figures 4 and 5). The high MBT concentration (2599 ng g^{-1} Sn MBT) suggests that there could be acceleration of bioactivity because of the sea warming in summer.

In winter 160 ng g^{-1} Sn MBT, 410 ng g^{-1} Sn DBT and 530 ng g^{-1} Sn TBT were determined while 302 ng g^{-1} Sn MBT, 919 ng g^{-1} Sn DBT and 1609 ng g^{-1} Sn TBT after the summer period analysis in Station 7 with 450-500 boat capacity. 400 ng g^{-1} Sn DBT and 280 ng g^{-1} Sn TBT were detected in the reference station in winter period and in summer period, with 416 ng g^{-1} Sn MBT. 813 ng g^{-1} Sn DBT and 250 ng g^{-1} Sn TBT being measured (Figures 3, 4, 5). Although the marina (450-500 boat capacity) is running at full capacity both in winter and summer seasons, the relative low levels of TBT in winter could be a reason for intense degredation in winters. In this case, detecting both MBT values in marina and DBT level 1.5 times more than TBT level in reference station 7 are shown as evidence. The high TBT level measured in summer may be the result of heavy marine traffic, boat yard inputs and cruise ships of large tonnage. The reason for low levels of TBT in marinas may be due to the small boat yard as compared with the other marinas.

In winter period, level of DBT was almost 2 times more than that of TBT in station 6 and in summer period measured DBT (1371 ng g^{-1} Sn) and MBT (565 ng g^{-1} Sn) values were higher could indicate that bioactivation starting at the end of the winter period continuously increases in summer period in the region. Reference station 6 is opened to usage as beach by people and located far from maritime activities, which may explain for values less than previously measured values.

Station 3 is located in an open bay and consists of pier along the cost line, which is distinguishable from other marinas and ports. Following the winter sampling period, only DBT was measured as 808 ng g^{-1} Sn in and around harbour, the reason for which until 2005 there were no customs gates in the region and foreign boats to the region especially preferred Ceşme Marina (Station 5) and similar ports, there existed military zone prohibited for ships to enter and thus no suitable boat yard in the region. Because ships are maintained in different regions, go out for fishing and then prefer the port. Çakalburnu to protect vessels from weather conditions, values of tin compounds may be found to be low in Station 3. Winter analyses determined only DBT concentration because of either transformation of low level TBT to DBT due to biodegradation or continental convection. At Foca Harbour (Station 3) 316 ng g^{-1} Sn MBT, 598 ng g^{-1} Sn DBT and 1275 ng g^{-1} Sn TBT values were determined but in reference station 428 ng g^{-1} Sn MBT, 473 ng g^{-1} Sn DBT and 202 ng g^{-1} Sn TBT values were determined. During summer period 4 large passenger ferry boat continuously cruise between Greek Islands and Foca Harbour in Aegean Sea and wait for their turns anchored in Foca Harbour, which may explain for higher values of OTC's in analyses of summer period.

Such high levels of OTS's determined at all stations in summer-winter periods along Aegean seashore were because of too much affiliated boats in the region (in summer-winter almost 100% capacity utilization or higher at all marinas) and due to TBT easily likely to be connected to sediment levels of OTC's were higher. Also, since the worldwidely introduction of prohibitions concerning usage of TBT in vessel paints, the regular observation has shown that TBT-based paints are stil used on boats less than 25m illegally and may therefore lead to high levels of TBT concentrations especially in marinas (Ceulemans *et al*., 1998).

In all stations levels of other organic tin compounds (MBT and DBT) may be determined high because of decomposition of TBT by biological separators. Especially in summer increased levels of MBT and DBT may indicate that biological separators are more than in summer period than the winter period. Also reference stations may have been contaminated with TBT carried down by currents from the marinas. In addition, these areas may contaminated with organic tin compounds because of existing transport activities at the ports in the region and such seashores being used for stopover by tourist cruise ships especially in summer.

5. Conclusions

Despite their ban, organotin are still of concern in the marine environment mainly due to the sequestration by sediments that occurred during the pre-ban period, which lead them to act nowadays as a secondary source (Sousa *et al.,* 2014).

The values obtained in this study revealed that important marinas, harbours, fishing shelters and slipways of the Aegean Sea have already been contaminated with OTC's. On the other hand, even less active and smaller shelters farther away from the maritime activities and some beaches and piers suitable for swimming have been too much contaminated with OTC's caused by flows of convection, biological fragmentation, maritime activities or terrestrial inputs.

High levels of tin compounds measured in summer-winter period along the Cost of Aegean Sea may be result of the numerous marinas (operating 100% or more capacity almost all year long) and strong adsorption tendency of TBT. Additionally, high concentrations of TBT suggesting the illegal usage of TBT-based antifouling paints on ships smaller than 25 m (Ceulemans *et al*., 1998). Furthermore, ongoing contamination of Aegean Sea could be consequence of leaching from the boat painted before the ban, or the compounds' long-lasting effectiveness time (5-7 years) (Yozukmaz *et al*., 2011).

TBT and DBT levels especially in marinas and concentrations of all stations were also found as high as in harbor with heavy traffic across the world. Survey research from all over the world reported that organic tin pollution is still a matter of concern. The two-way research revealed that there are still significant TBT pollution along coastal zones of Pacific, Atlantic, India Oceans and of marinas and harbors (Ladislao, 2008).

Table 2. Previous studies on butyltin compounds' levels from the world (ng g^{-1} Sn dw) (Ladislao, 2008)

Regions	**MBT**	**DBT**	**TBT**
Marinas of the U.S.A.			
East–West Canada Coast	nd-330	nd-100	nd-5100
Crystal Lake	21.3-320	59-350	1.5-14000
Marinas of Asia			
Osaka Harbor	nd	nd	102.100
Malaysian Coast	5.0 - 360	3.8-310	2.8-1100
West coast of India	nd	nd-469	5- 2384
Marinas of Europe			
North-west Sicily Coastline	nd	nd	3-27
Portuguese Coast	5.2-78	5.3-65	3.8-12.4
North Cost line of Spain	860-2870	150-710	50-5480
South-west of France	1.0-125	nd-87	nd-89
Marinas of Turkey			
Aegean Sea (This study)	nd-2598	nd-1371	nd-3008

In conclusion; comparison of levels between measured OTC's levels along Turkey Coast of Aegean Sea with those levels previously found in marinas along the Mediterranean shows that they are rather high (Table 2). At the end of the study, we determined that the total TBT concentrations in the sediment samples showed the significant spatio-temporal changes.

Acknowledgements

This research was financially supported by the Foundation of Scientific Research of the Ege University (BAP Project Number: 2009/SUF/018) and special thanks are extended to The Scientific and Technical Research Council of Turkey (TUBITAK–ATAL) for their technical contribution.

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OCEANOGRAPHIC AND POLLUTION MONITORING STUDIES AT THE EIGHTIES IN THE AEGEAN SEA

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1. Introduction

Marine pollution is a phenomena not easily understandable by its direct effects. When pollution of the seas is to be discussed, properties of the marine environment that differs from fresh water bodies are also to be noted. Among these properties, salinity seems to be the most important factor, although salinity is also a general indicator of dissolved solids in fresh water bodies, too.

Salinity seems to be the most important factor to effect several ecological variables that usually define pollution of the sea. Temperature, for example, is one of these variables and is in direct relation to salinity, as warm seas of the world are generally more saline. Fresh water input to the sea environment is another important factor in relation to salinity, which also defines the pollution load to be discharged into the marine environment (Reid and Wood, 1976). Quality of the living elements of the marine ecosystem largely depends on the salinity level and fluctuating salinity tolerances of the marine organisms define a biological status in the sea environment which sometimes is observed as "pollution". Eutrophication is a phenomena described by such conditions and it usually occurs at around freshwater inlet parts such as river deltas and closed water bodies such as estuaries. Excessive salinity fluctuations are usually seen at such environments, in relation to general quality jumps.

Rising seawater temperature for constant (or decreasing) freshwater flow into the sea means rise in salinity. These two are even more closely interrelated in warm seas, due to the high evaporation rates at warm climates. As salinity increases, due to physicochemical laws saturation concentrations of water soluble matter including atmospheric gases decrease. Sparsely soluble oxygen gas which is the most important element of life in aerobic environment therefore is even more limited in saline waters in comparison to low temperature seas. This decrease in saturation concentration of dissolved oxygen due to increased salinity is even more so, due to higher water temperatures that limits dissolution rates according to Henry's law. Decrease in saturation concentration causes aerobic life forms to switch into anaerobic forms which are the lowest grade of environmental quality in water bodies.

To add to what has been put forth above, it can be suggested that warm and saline seas be more prone to organic and chemical pollution than less saline temperate seas. On the contrary microbiological pollution is less effective and is subject to shorter T_{90} periods in warm and saline seas.

Definition of marine pollution is closely related to the geographical location, oceanographic properties as well as the challenging ways of using the sea environment. What is meant by uses of the sea environment can be described by basic definitions of the law of the sea.

In this paper results of a research program on pollution of the Aegean Sea, with a Turkish shoreline of 2805 km comprises the most interfering sea of the Anatolian peninsula, is being studied and evaluated. This research program being carried out under the auspices of the UNEP/MAP-Med Pol II international project covering years 1983-1985 has been conducted by Dokuz Eylul University under the scientific guidance of the authors (Izdar and Muezzinoglu, 1983, Izdar and Muezzinoglu 1984, MED-POL II, 1983, MED-POL II, 1984, MED-POL II, 1985).

2. Status of the Aegean Sea

In comparison to the other two International seas, Aegean is the sea which Turkey has the longest shoreline. Complex nature of the shoreline forming bays, estuaries and small peninsula and islands mainly in the form of rocks and sea-mountain tops emerging from the seabed, define specific sea water movement patterns. As these land and sea mountains are lining up in a form perpendicular to the shoreline, typical Aegean climate is effective at a very long distance inland. This geographical structure is in contrast to the Eastern Mediterranean and Black Sea Coasts of Anatolia where narrow ribbons of sea-climate can be seen in parallel to the shoreline. This property of the Aegean region of the country causes many social, cultural, economic results while at the same time creates interesting pollutional aspects. As rainy Aegean climate is seen at a large part of the country, agricultural potential is highly affected thus causing pollutional by-products of chemical fertilizer and pesticides in storm water washings reaching the Aegean rivers to find their way into the sea. In parallel to agricultural possibilities, cultural and social environment in the region is rich with a large number of inhabitants at many cities and townships. Both at these agglomerations themselves and industries being located around them contribute to the pollutional status of the coastal waters and rivers to find their way into the sea.

Seawater mass movement in the Aegean is very peculiar, too. Freshwater inputs of Anatolian rivers and creeks are usually unimportant at a large scale except for the estuaries they discharge. In these estuaries they usually cause a potential for eutrophication due to the relatively limited water movements and high nutritional load these river waters carry. But at a large scale there are two main water inlet/outlet ports in the Aegean: two open-sea ports at east and west of Cretes and the Dardanelles. Thus general pattern of water mass movement indicates a rush towards north near Turkish Coasts to replace approximately 6500 m^3/sec of 22 %o salinity Marmara waters. This Marmara water continues to flow like river at the large part of the northern Aegean forming a counterclockwise current towards western shores (Phillippe and Harang, 1982). Then getting weaker and slower as it goes further away from Dardanelles, Marmara waters mix well with Aegean waters and is connected into the Eastern Mediterranean. Marmara waters of low salinity, density and temperature until they mix well with the Mediterranean high salinity, density and temperature waters create a double layered stratification in the North Eastern Aegean. This stratified part of the sea is more pronounced and larger during summertime due to the very high evaporation rates in the Aegean. The pattern of water mass movements so far described has been followed by seasonal salinity and temperature profiles at 126 monitoring points in the Aegean over a period more than 2.5 years. It is obvious that much more can be said and written over such tremendous heap of field data. Figure 1 shows the general layout of study area.

Due to the direction of currents and waves shallow sand beaches are formed in the southern and innermost parts of the many bays in the Turkish Aegean coast. In fact the eastern shores of the Aegean are over a large continental shelf, which continuously erodes under the south to northeast directed currents. The shallow bays and estuaries which are formed over the land between perpendicularly oriented mountains are seen to be encircled by numerous islands, mainly to be described as mountain tops over the shallow Anatolian shelf. Most of these bigger islands are called Aegean islands belonging to Greece. Due to the direction of the currents Turkish Aegean shoreline is the receiving medium to the pollution load transported from Eastern Mediterranean and Aegean. To this added are the many rivers, streams and creeks discharging their waters from very large and densely populated catchment areas. Many touristic and some industrial localities over the Aegean coasts contribute to this pollution. But most important 'among these sources are the ship and tanker traffic towards Dardanelles.

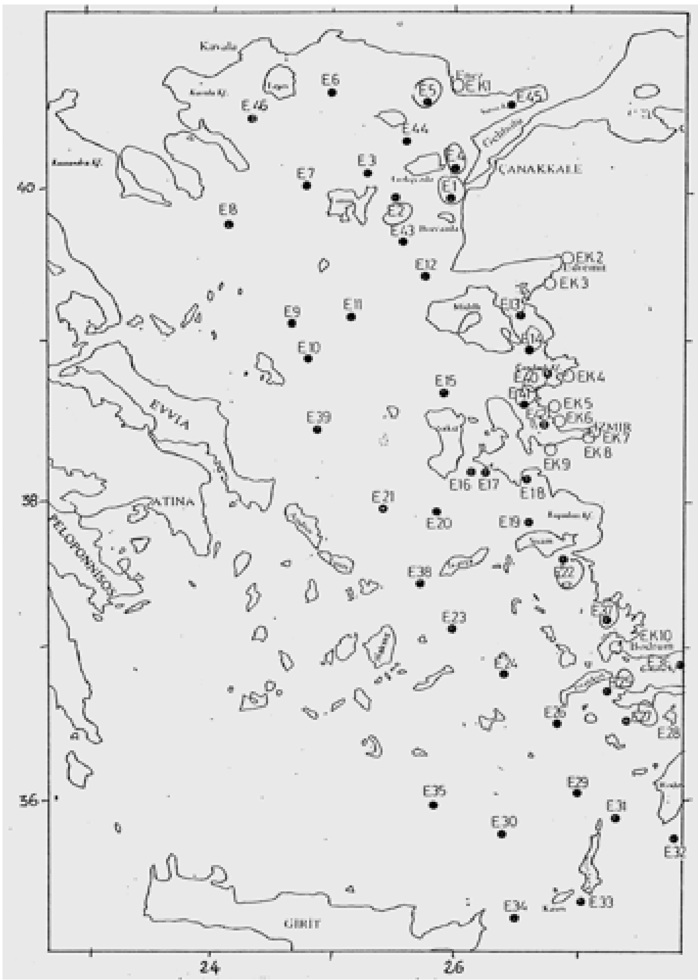

Figure 1. Monitoring study area in the Aegean Sea

Aegean which has been the birthplace to the western civilization has a deep influence over the Anatolian land because of the climatic, cultural, esthetic and trading effects. On the contrary, land contributes to the shallow Aegean waters by erosion material from the catchment areas as well as by organic debris from dense population for thousands of years. Many famous antique city ruins attributed to thousands of years A.D, lay under the alluvial layers especially at ancient deltas of major Aegean rivers. Some of these cities have been shown to be above a million populations like the cities of today. And just like the pollution problems of today, these ancient big cities had a sewerage and sewage disposal problem. It can be suggested by a little bit of imagination that waste materials thrown in to the rivers or directly into the sea by famous philosophers of Thales from Miletos, Herodot from Bodrum (Halikarnassos), Homeros from Izmir (Smyrna) and their contemporaries still must be under the sediments of the sea or the river bed, in a putrefied from. In order to be able to see the dimensions of the problem, one must remember that during the Roman Era in Anatolia, a census result showed that 21 million inhabitants were living in the peninsula, which is the population of Anatolia reached again in about nineteen sixties. Of course people living in both sides of the Aegean has been doubled during the 2.5 decades with more polluting influence than doubling only. Ship and tanker traffic in the Aegean has been over increased too, showing a larger potential to pollution than the inhabited population. And in both sides of the Sea industrial effluents and agricultural runoff become more and more every year.

3. Methods Used in the Study and Results

This pollution monitoring study covers 9 seasonal cruises between 1983-1986 covering 126 estuarine, coastal and open sea stations fixed with their latitudes and longitudes. Cruise number and date has been showing at the Table 1. Among these stations are 40 sources, coastal and open sea (reference) points all over the Aegean, 53 estuarine and coastal stations at Candarli Bay, 23 estuarine stations at Great Meander Delta. Fixed locations of the stations are indicated in Figure 1.

Monitored parameters as well as their sampling, preserving, analysis methods are in accordance with UNEP/MED POL II project. All the monitoring information according the sampling and measurement date, depth, units, and station codes are being stored and awaits for further processing in our University computer system in the form of matrices having tens of thousands of elements. Only a few representative points and parameters have been selected and evaluated in this paper.

3.1. Basic Oceanographic Parameters

Spatial and temporal variations of salinity and salinity profiles with depth have been followed in order to evaluate the water mass movements in the Aegean. This method has been found to be more satisfactory than the usual way of current measurements, because current measurements give almost no sound result pertaining to the largely variable and weak currents which are effective only over a large scale. Salinities of the two adjoining seas and freshwater streams are clearly different than the Aegean, thus following their pathways in the Aegean is a good indication of the water mass movements over large distances.

Purely Aegean waters monitored over the open sea (reference) points have a narrow salinity variation ranging between %0 37.6 - 39.2. These figures are obtained from analog records taken at stations over the depth and counts only the maximum salinity at each profile. Lower end of the range is in the North while figures above 38.8 are always met in the South of the Aegean.

Table 1. Cruise number and date of R/V K.Piri Reis in the Aegean Sea

Cruise no	Cruise date	Study Area
83/1	5-20 January 1983	Northern Aegean
83/2	5-20 February 1983	Southern Aegean
83/5	16-30 April 1983	Northern Aegean
83/7	16-30 May 1983	Southern Aegean
83/8	5-20 July 1983	Northern Aegean
83/9	5-20 August 1983	Southern Aegean
83/11	5-20 October 1983	Southern Aegean
83/12	5-20 November 1983	Northern Aegean
84/1	28 February-5 March 1984	Southern Aegean
84/2	12-20 March 1984	Northern Aegean
84/6	31 May-4 June 1984	Southern Aegean
84/7	7-12 June 1984	Southern Aegean
84/8	1-8 July 1984	Northern Aegean
84/9	9-17 July 1984	Southern Aegean
84/12	3-11 September 1984	Southern Aegean
84/13	11-19 September 1984	Northern Aegean
84/16	10-20 November 1984	Northern Aegean
84/17	20 November-1 December 1984	Southern Aegean
85/1	7-16 January 1985	Southern Aegean
85/2	18-23 January 1985	Northern Aegean
85/7	18-25 April 1985	Northern Aegean
85/8	25 April-6 May 1985	Southern Aegean
85/10	3-10 July 1985	Southern Aegean
85/11	15-21 July 1985	Northern Aegean
85/15	20-26 October 1985	Northern Aegean
85/16	1-7 November 1985	Southern Aegean
86/1	6-12 January 1986	Southern Aegean
86/2	14-20 January 1986	Northern Aegean
86/7	25 April-1 May 1986	Northern Aegean
86/8	3-10 May 1986	Southern Aegean
86/12	7-13 July 1986	Southern Aegean
86/13	14-20 July 1986	Northern Aegean

Low salinity Marmara waters spread out towards the North after flushing into the Aegean forming a field. That field is mainly at the surface of the saline Aegean waters thus causing stratification. Both halocline depth and its aim are changing with distance to Dardanelles and according to the season. Usually the salinity profile shows an inflection over a depth of 2-20 m. from the sea surface. At the same fixed location, lower end of this inflection depth is seen at rainy and cool seasons while in summer end especially end of summer studies this low salinity layer is still thicker. This can be described by very high evaporation rates in the Aegean and the Mediterranean thus causing more Black Sea water flush into the Aegean to restore the water level. All these special salinity profiles are seen in the Northern Aegean only. In the South except for a few estuaries no inflection in salinity profile nor any other kind of stratification can be met. Although the Aegean is usually deeper at the South no important oceanographic parameter changes with depth, except for the depths of more than 200 m where light penetration is restricted and a constant water temperature of 14.5°C is reached. In the Aegean the constant temperature thermocline is buried under 200 m. depth at open sea and coastal parts. Along with this permanent but usually unimportant thermocline, at some coastal stations a weak seasonal thermocline can be seen at 30-50 m. dept. But these thermoclines are not permanent and therefore are undependable as far as sea disposal project are concerned.

pH values in the Aegean vary between 7.0 - 8.4 depending upon the changing solubility of CO_2 with temperature and diurnal algal activity. Mostly the value is 8.0-8.2 and very low pH values which can be described as pollution indicator could not have been found anywhere at any depth. pH values found during this study vary from the mean within the 7.5% normal diurnal fluctuation range.

Dissolved oxygen (DO) In the Aegean waters has low saturation values due to high salinities and temperatures. Therefore, DO must be critical parameter in the Aegean, having in mind the possibility of presence of DO in the uppermost euphotic zones only, in contrast to its aggravated consumption by organic pollutants. But probably due to the unimportant organic pollution input, high reaction rates induced by the rough sea waves and relative unimportance of the stratifications thus causing a well intermixing sea, DO is not limiting indicator of pollution. At many of the stations studied, surface DO values are much above the saturation figures. DO values are measured by automatic recording probe type instruments according to the depth. Probe is calibrated by frequent on-board Winkler tests which are the standard method for DO measurement.

Basic oceanographic parameters discussed above give a good indication of the basic pollutional aspects of the Aegean. Of course it is not possible to submit here all the relevant data which has been the basis to this evaluation. But several critical points have been selected for further submission of information and temperature, salinity and dissolved oxygen variations with respect to depth have been plotted according to the season. Among other oceanographic parameters monitored in this study are the conductivity, redox potential, and turbidity which are not evaluated in this presentation.

3.2. Nutrients

Excess productivity of the sea environment is the important phenomena in the Aegean as well as in the Mediterranean as a whole. What differs is the Aegean connection to the Black Sea, which is a sea known to be highly productive. That is why high nutrient content of the, Black Sea after limited intermixing with Aegean waters in Marmara Sea flush into the Aegean with still rather high phosphorus and nitrogen content, thus fertilizing the Aegean up to a certain level of productivity. This fact has been first indicated by data from previous cruises of Chain 21 research in this area (Chain 21 Cruise 175). According to this study Mediterranean waters connected to the Aegean at the east of Cretes contain maximum 0.2 ppm phosphorus even at 1000 m. depth, while at Marmara Sea near outlet to Dardanelles waters contain 1.0 ppm from surface down a few hundred meters depth. At the Dardenelles which is only a few hundred meters deep phosphorus is only 0.2 ppm at the outermost end such as- near Limnos That shows the limiting effect of shallowness of Dardanelles strait to lock up excess fertility in Marmara. In the contrary regular phosphorus values at almost all depths is less than or equal to 0,1 ppm at the South Aegean. The difference of 0.1 ppm phosphorus in the South and 0.2 ppm in the North is absorbed by the fish stocks of the Aegean. For closed water bodies such as bays and estuaries, 0.1 ppm dissolved phosphorus has been defined as the critical value at which eutrophication may start. That Is why critical' phosphorus values are met in the Aegean even without much polluting influence of the humanity. The situation is quite similar in the Aegean for inorganic nitrogen compounds. Chain 21 study shows that in contrast to 5 ppm nitrate nitrogen near Dardenelles, less than 1 ppm of this nutrient is met at the South. According to this study, nutrients are specifically analyzed at the estuaries of major river mouths. At these estuaries fresh water and saline water layers are separately analyzed for total phosphorus and total inorganic nitrogen phosphorus is found to be 65-140 mg/m3 range in the fresh water which is supposed to be the most fertile layer whereas it goes down to 2-220 mg/m^3 depending on the locality at the saline water layers beneath. Although saline waters - originate from the open sea, this increased phosphorus content may be explained by increased depth in this saline layer. It can be postulated that dead organic matter settle down to this layer, thus increasing phosphorus uptake rates. Phosphorus in the Aegean estuaries must be at a critical level if one considers that the 100 mg/m^3 eutrophication limit is passed from time to time. Phosphorus content of suspended matter and estuarine sediment are found to be high, again indicating excess fertility in these river mouths. Total nitrogen content of the estuarine waters studied vary between 0.3-8.3 g/m^3 with a median of about 3 g/m^3. When this broad range is compared with the 0.5 g/m^3 eutrophication limit for closed water bodies, it can be stated that in Anatolian estuarine areas well nutrition is a phenomenon that aggravates vitality of the Aegean. At certain seasons saline estuarine waters neighboring the bottom sediments contain 60 mg/kg total nitrogen 90 mg/kg total phosphorus.

3.3. Fecal Coliforms

Fecal coliform parameter depends on an elaborate, time consuming and expensive test than total coliform test. But is a better indication of human fecal contamination as it refers to a subgroup of coliform bacteria inhabiting in the intestines of warm blooded animals, only. These coliforms are organisms that do not reproduce in the saline, well-aerated and high redox potential sea environment. Such properties of the sea environment in combination with the high intensity of solar radiation form the disinfecting power of the seas, and this power is still more effective in the Aegean. The period of time elapsing to reduce original number of fecal coliforms to one tenth of this number is known as T_{90} period. T_{90} is a parameter mostly utilized as a critical criterion in sea disposal design projects. T_{90} values in Aegean and Mediterranean Sea environments are usually in the order of less than 1 hour.

Fecal coliform counts are carried out in this study as an immediate test on board during the cruises. Normally at open sea and outer coastal stations no fecal coliform can be found. But occasionally at these stations some higher figures are seen. As the distance from the land is too much to enable these organisms to travel within their T_{90} period, it is quite probable that these occasional fecal coliform pollution is due to a ship or yacht passed within a few hours period. Frequent fecal coliform measurements are made at the estuarine and coastal stations, but except for a few statistically inescapable incidences, no fecal coliforms are seen.

3.4. Petroleum Hydrocarbons

In this project "total petroleum hydrocarbons" are extensively studied by infrared spectrofluorometry on sea sediments and surface waters. Along with MED POL II project a deeper investigation has been carried out at 15 selected stations to see the origins of petroleum pollution in the Aegean. In the more detailed study, extracted petroleum hydrocarbons are analyzed by gas chromatography to find out their major fractions. Spectral finger prints of the petroleum extracts thus taken from the seawater and sediments give clue to the age and origin of pollution. It is found at the end of this part of the study that the Aegean generally is polluted by petroleum hydrocarbons, mostly by crude oil (Topcu, 1985). The levels of petroleum pollution in the Aegean is much above elsewhere at some points of this investigation. Although there is no generally accepted reference value for petroleum pollution in the sea, presence of 1 mg/m^3 (ppb) total petroleum hydrocarbons (TPH) in the sea is a good round figure to compare. In this study at many places in the Aegean this criterion is passed, for example at station 47 at the outlet of Dardanelles by Limnos in 1984 Fall seawater TPH has been found to be 13 mg/m^3. Sediment TPH values ore generally much higher than seawater and at the same sampling time and location, sediment TPH has been found to be 31.4 mg/kg. During other samplings of the same station TPH is found to be sometimes more, sometimes less than the 1 mg/m^3 reference level. In the South Aegean station 60, on the other hand, at the 1984 Summer study, TPH in water is 0.18 mg/m^3 and in sediment 0.41 mg/m3. In station number 68 which is the open sea station at the Northwestern Aegean near Saloniki (Northern Greece), during 1984 Spring and Summer seasons, seawater TPH's of 4.5-9.0 $mg/m^3$are found. Sediment TPH's of 0.3-9.5 mg/kg have been found to exist. All these values are much above the findings of Aegean studies mentioned in (Civili and Saverio, 1985) before. The results show that petroleum contamination is highly random phenomena, depending probably on the recent traffic incidences within a few hours at or near the sampling location. After a logical period of time seawater disperses itself by several mechanisms, but sediment levels build up almost everywhere.

4. Discussion of Results and Conclusions

In this study 9 sampling and analyses cruises at 126 fixed station in the Aegean have been covered to take in situ readings of basic oceanographic parameters with depth and to sample seawater and sea sediments for further analyses. Among the in situ measurements basic oceanographic parameters of salinity, seawater temperature, redox potential, conductivity, turbidity, dissolved oxygen, pH and meteorological observations are to be noted. Currents are measured only at the beginning of the study during the first year visits. But data obtained from both direct reading type and continuous current meters indicate such random and variable wind currents that continuation of this current measurement part of the study has been found to be irrational. Along with in situ measurements some analyses are carried out right after the time of sampling, on board. These parameters are suspended matter in water, microbiological pollution, biological pollution indicators like BOD_5 and COD and nutrients in seawater and sediments. Some other parameters like petroleum, toxic heavy metals, pesticide residues are analyses at the end of the cruise, therefore their samples are taken and preserved. Sediment and biota samples are frozen, petroleum water samples are added by CCl_4 and heavy metal samples are acidified for this purpose. The results of all these studies and analyses are being constantly fed into a data storage system to be analyzed and evaluated from time to time.

Turkey which is the owner of the eastern coasts of Aegean has made a lot of investment in this monitoring and data collection project. This investment is both in monetary and man-power. The aim is only to get acquainted with the natural cleansing processes in order to be able to decide to the degree of pollution abatement necessary to keep this cradle of ancient civilizations as unpolluted as in the past history. To conclude what is to be done for the foreseeable future, petroleum contamination risk must be eliminated by taking appropriate action against transit sea traffic. What comes next is the necessity to control phosphorus input into the Aegean which is another risk for the bays and estuaries of the Aegean shores.

In order to keep this inherited sea of natural beauty an ancient culture away from pollution, the countries owning the coasts and using the traffic lines must come together and note urgent problems.

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R/V Chain 21 and R/V Atlantis 175 cruises.

ECOTOXICOLOGICAL STUDIES CARRIED OUT ALONG THE AEGEAN COAST OF TURKEY

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1. Introduction

Industrial revolution caused increase in waste production due to the overuse of the resources since the 1700's. The excessive release of toxic chemicals to the environment, especially right after the World War II, compelled the description of Ecotoxicology to expand, including the effects of the toxic chemicals on the environment, more than on human, and it was defined as Environmental Toxicology in the literature.

It is Ecology that investigates the effects of the possible negative environmental changes on the organisms. Eco-toxicology aims to research the pressure that is caused by the pollutants on the organisms at individual, population and community levels; besides detecting the pollutants that cause toxic effects. Consequently, "ecotoxicology is a discipline of science that researches the distribution of the pollutants in the biosphere and the mechanisms of effects of the pollutants in varied ecosystems" (Parlak *et al*., 2009).

The term, ecotoxicology, was initially used by a French Academy of Sciences member Prof. Réné Truhaut in 1969; thus it is relatively a new discipline of science. Ecotoxicological studies do not have a deep background in Turkey, especially in Aegean Sea Coast. Studies had been started as the aquatic pollution emerged in all fresh water and marine ecosystems in Turkey and still being carried on. Ecotoxicological studies, as mentioned, are divided into two groups.

a. Detection of the distribution and the amount of pollutants in water, sediment and organisms,

b. Formation of the standardizable test methods for the detection of the negative effects of the pollutant chemicals on the organisms in aquatic environments.

Ecotoxicological studies in Aegean Sea Coast are categorized in those two groups. It is explained in another section of the book; how to measure the amount of the pollutants such as especially heavy metal, PAH, PCB, which are commonly found in water, sediment and organism; and how to evaluate the results. In this section of the book, it will be explained that how the analytically measurable or unmeasurable pollutants affect the organisms in Aegean Sea ecosystem.

The studies are focused in Izmir Gulf. It is investigated that the effectiveness of the brooks on Izmir Gulf and the gulf itself, which is the collection area of the industrial, agricultural and aerial pollutants released from the city Izmir that has been industrialized and urbanized rapidly since the 1960's.

2. The ecotoxicological studies performed in Izmir Bay

The frequency of phytoplankton blooms a related with the increasing pollution. The relation between excessive phytoplankton growth in Izmir Bay and the concentration of the essential elements such as Cu, Fn and Zn have been worked on in a study. In red tide blooms, which had excessively occurred three times in 1991, it was observed that *Noctiluca scintillans* contained maximum Fe (1233 µg Fe/g dw); *Prorocentrum micans* contained maximum Cu (31.1 µg Cu/g dw) and *Eutreptiella gymnastic* contained maximum Zn (1033 µg Zn/g dw). In the sea water analyses, it was noted that the Fe, Cu and Zn containing plankton that are found in 4-meter-depth from the surface where the plankton production is well supported, had grown in the same monthly period as the concentrations of Fe, Cu, and Zn reached the maximum levels (Parlak *et al*., 1994a).

In a study that was carried out by Arınc and Sen (1999), hepatic cytochrome P4501A and 7-ethoxyresorufin O-deethylase (EROD) enzymes of leaping mullet (*Liza saliens*) and common sole (*Solea vulgaris*) were measured and used as biomarkers to research the pollution of PCB and PAH. It was pointed out that high enzyme activities were observed, which meant that Inner and Middle parts of Izmir Bay were highly contaminated with PAH and PCB (Arinc and Sen, 1999).

Blood parameters such as white blood cells (leucocyte, WBC), red blood cells (erythrocyte, RBC), hemoglobin, hematocrit, thrombocyte and mean cell hemoglobin concentration (MHCH) of *Gobius niger*, that were seasonally collected with fishing rod and seine from the coasts of Tuzla, Bostanlı, Inciraltı, Urla and Çeşme between October 1995-October 1997, were measured. In the microscopical studies, some histopathological changes due to the environmental conditions have been observed. An increasement of immature red blood cells has been observed due to the environmental pollution. Ovoid shape seen in the normal red blood cells have been transformed totally and a marked increasement of degenerated red blood cells is obvious. The membranes and ovoid shape of the nuclei seen in the normal red blood cells has been changed fusiform and spheric shape and echinoid view. Dense and compact lymphocytes have been observed instead of small and spheric lymphocytes of the normal lymph (Katalay and Parlak, 2002).Marine pollution especially in the industrialized regions, directly or indirectly lead to toxicologic and genotoxic risks for human and marine biota. Mutagens in aquatic ecosystems are one of the significant reasons of pollution. Increasing tumor formation has been observed in tissues of fish consumed recently. Although this is partly due to natural causes, it has been determined that it is largely a consequence of exposure with mutagenic and carcinogenic substances. One of the important features of the carcinogenic and mutagenic substances is that they are effective even in very low concentrations. It is not possible to detect analytically chemical structure of such substances present in the tissues using currently available chemical methods. Thus, the methods based on screening the carcinogenic and mutagenic substances in the biological habitats using biological indicators (biomarker) have recently gained importance (Kotelevtsev and Stepanova, 1995). Cheap and practical methods have been developed to explore presence of mutagenic and/or carcinogenic substances in the environment by determining their impacts on the living organisms, including Ames assay, Umu test, Micronucleus frequency and Comet test. As aquatic organisms take important place in the nutrition of human population and many carcinogen and mutagen chemicals were detected in this aquatic organisms, so it is very important and crucial to search and monitor genotoxic effects (Kotelevtsev and Stepanova, 1995).

In a study that was conducted by Boyacıoğlu *et al*. (2011), it was investigated whether the tissues of mussels and fish that were collected from Izmir Bay had mutagenic potential; and gained significant results. Black goby (*Gobius niger*) and mussels (*Mytilus galloprovincialis*) were collected from Alsancak, Alsancak Port, Alaybey Shipyard, Karşıyaka, Bostanlı, Göztepe, Konak and Pasaport stations. Liver and muscle tissues of black goby and soft tissues of mussel were extracted and used in Ames test (without metabolic activation) to see the mutagenicity. In the study, mutagenicity was observed in the liver tissue extracts of the fish that were collected from Pasaport, but not in the ones from Bostanlı. Extracts of mussel samples that were collected from 8 stations were analysed and weak mutagenicity was observed only in the ones collected from Alsancak Port, in the tests with *S.typhimurium* TA98 strain. It was determined that Alsancak region was mutagenically polluted and the pollution was caused by the pollutants that lead to frameshift mutation. Micronuclei test, which is used for the same purpose, is a system of mutagenicity testing used for determining changes in DNA fragments such as micronuclei in the cytoplasm of interphase cells caused by the pollution and chemicals in the environment. The damage in the DNA, caused by genotoxic pollutants, is the initial response observed in the aquatic organisms. Micronuclei test is widely used to determine genotoxic effects due to the reliability of the results and easiness-to-perform. Erythrocytes and gills of black goby (*Gobius niger*) and hemolymph of mussels (*Mytilus galloprovincialis*) that were collected from Izmir Bay were used in Micronuclei test to determine whether it is harmed in DNA levels or not. The organisms used in the micronuclei test were collected from the inner part of Izmir Bay, where the pollution was observed (Alsancak Port, Alaybey Shipyard, Karşıyaka, Bostanlı Port, Göztepe, Konak, Pasaport Port). Micronuclei and binuclei frequencies increased where the pollution was significantly high in Alsancak Port region and Alaybey, due to the wastes released from the shipyard (Arslan *et al*., 2010).

3. The ecotoxicological studies performed in the brooks reaching to Izmir Bay

The brooks that reach to Izmir Bay carries various pollutants that contain complex wastes, and are mainly responsible for the pollution of the bay. The variety of the wastes carried to the bay by the brooks makes it even harder to apply analytical methods as it would be time-consuming and uneconomic. Thus, standardized ecotoxicological test methods have been used to determine the quality and the toxic effects of the water samples taken from the brooks. It was researched whether highly polluted Melez Brook, which is one of the most important sources that reach to the bay, had any effects on algae development, in the 1990's. *Enteromorpha linza* were singled out by regarding the primary importance of herbal production and its ecological dominance, and used for detecting the toxicity of brook water by measuring rhizoidal development. Algae that were used as test subject and exposed to brook water were observed and significant decreases were noted in the number of the individuals growing rhizoid, number of rhizoids and rhizoid lengths, contrary to the control group (Parlak *et al*., 1994b). Sediments around the industrialized and populous regions such as Izmir, which is a metropolitan territory in western Turkey, are the main reason for pollution. Yegane *et al*. (2008) monitored the sediment toxicity in the brooks that drain to Izmir Bay by using water flea, *Daphnia magna* as test organism. The collected sediments were elutriated with pure water and the toxic effects of the elutriates were evaluated. Lethal toxicity of the elutriates were determined by 192-s acute toxicity test. "Immobilization" was used as indices in acute tests. Survival age at first reproduction, number of brood produced and the number of young per adult were used as indices in chronic test. According to acute test results calculated LC_{50} (192-h) were 79.025% 57.321%, 81.603% for Melez, Halkapınar and Manda streams respectively. The diluted elutriates of Bornova Stream were noted as the most toxic among the others as LC_{50} (1.5 hour) 67.273%. *D. magna* had been exposed to sub-lethal dilutions of sediment elutriates and the results showed that all of elutriates produced positive effects (hormeosis).

Genotoxic and mutagenic effects in the sediment samples collected in December 1995 from the stations on Manda, Melez, Laka, Bostanlı, Bornova and Gediz streams that drain to Izmir Bay were studied by Ames mutagenicity test by using *S.typhimurium* TA98 and TA100 strains. According to the results of the study, it was noted that the rivers draining to the inner parts of the bay were important sources of mutagenic activity due to their pollution load and the statistical studies showed that the pollution in the inner, middle and outer parts of the bay significantly differed (Boyacioglu and Parlak, 2001).

The mutagenicity was tried to be determined by using *Salmonella typhimurium* TA98 and TA100 mutant strains in Ames test in the streams that drain to the inner parts of Izmir Bay such as Melez, Arap, Manda, Bornova and Bostanlı. Weak mutagenicity were determined in all streams in the test with TA98 as the test with TA100 demonstrated that the sediments collected from the line showed toxic character more than mutagenic (Boyacioglu *et al.,* 2002).

A study was performed to determine the potential adverse effects of sediments collected from five streams that reach to the inner part of Izmir Bay by using sea urchin, *Paracentrotus lividus* as test organism in the embryotoxicity test to see whether there is any correlation between chemicals and the toxicity or not. Toxicity tests demonstrated that all sediment samples were toxic except one sample at the lowest concentration (0.6 mg ml^{-1} ww). It was stated that the frequencies of developmental defects of *P. lividus* embryos increased significantly in all of the sediment samples. It was evaluated that all streams, where the sediment samples were collected from, were chemically similar. An important point to note was the excellent correlation between total organic carbon content of stream sediments and sea urchin *P. lividus* embryotoxicity data, but not with metal content (Oral *et al*., 2007).

In the studies on Gediz River; sediments from the delta of Gediz River, which is one of the most important bird areas protected as RAMSAR site, have been investigated for their potential mutagenicity in TA98 and TA100 strains of Salmonella typhimurium by performing Ames test (plate incorporation assay) without metabolic activation. Mutagenicity results for both strains showed that the sediment samples contained no mutagenic substance but most of them had toxic effects which decreased the growth of bacteria in all sampling sites (Boyacioglu *et al*., 2008a).

Nif Brook, which is one of the important water supplies in the territory, transports domestic and agricultural waste water of the drainage area to Gediz River, which reaches to Izmir Bay; besides industrial waste water of Turgutlu and industrial area of Manisa.

In water and sediment samples from 7 sites on Nif Brook and 1 site on Gediz River were studied for their mutagenic potential in TA98 and TA100 strains of *Salmonella typhimurium* using Ames test (without metabolic activation). Extracts of the sediment samples were assayed in five different concentrations, and mutagenicity results were obtained for two strains from different sampling sites. Without metabolic activation, sediment samples were either non-mutagenic, weakly mutagenic or strongly mutagenic; and water samples were found not to be mutagenic. It was noted that complex pollutants discharged to Nif Brook are accumulated in the sediment rather than in the water, and regarded to be lipo-soluble pollutants (Boyacioglu *et al*., 2008b).

Sediment and water samples collected from 5 stations in Nif Brook were investigated by using embryotoxicity test to assess the water quality. Sea urchin (*P. lividus*) embryos were utilized for evaluating the toxicity of water and sediment. The effects on developing embryos were evaluated by scoring developmental defects. The water and sediment samples were tested with 0.001, 0.01, 0.1 dilutions in natural sea water. All water and sediment samples of the brook were assessed to be toxic according to the sea urchin embryotoxicity results. Significant growth reduction depending on concentration at the early life stages and an increase in larval malformations as skeleton deformities at the *pluteus* stage were observed (approximately 59% in 0.001 ml/ml from station 5) in the embryotoxicity of water samples. The most polluted sediment samples displayed a dramatic embryotoxicity, up to approximately 98% developmental arrest in embryos reared in 0.1 g/ml of sediment from station 5 (Aslan *et al*., 2009).

Parlak *et al*. (2010) studied toxicity of water and sediment samples of Nif Brook using *Daphnia magna*, as another ecotoxicity test. The lethal toxicity of waters and sediments were evaluated by using the 48- h acute toxicity test. And also, sub-lethal toxicity of waters and sediments were evaluated by using 7-days chronic toxicity test. According to the acute test results, average 48h LC_{50} for *D. magna* was calculated as 6,8-12,67 µl/L for water samples; and as 6,826-38,038 µl/L for sediment samples; and then *D. magna* were exposed to sub-lethal concentrations. The results pointed out that all of the streams and their elutriates produced negative effects. Results of the study showed that, screening the toxicity of polluted waters and sediments by using *D. magna* gives better and more meaningful results than a quantitative analyze of toxic matters.

Another toxicology study on Nif Brook was performed by Katalay *et al*. (2012). The water of Nif Brook is polluted by industrial, domestic, and agricultural sources. As the water of the brook is used for domestic and industrial water supply as well as for irrigation, it is of great importance to know the toxicity potential for the natural populations. For this purpose, the standard test protocol for the short term phytotoxicity test method *OECD 201 Algal Growth Inhibition* has been evaluated with cultures of green algae *Desmodesmus* (=*Scenedesmus*) *subspicatus* as the representative of the first trophic level. The test had been used to assess the toxicity of both water and sediment samples from the brook. Five sampling sites from the brook were selected considering the type of pollution sources. The water samples were tested with 10, 20, 40, 60, 80 and 100% dilutions in a test medium. Extracts of sediment samples were assayed in three different concentrations (20, 40 and 100 mg/mL). The effects on the growth of *D. subspicatus* were evaluated by scoring cell numbers under the light microscope with a Neubauer haemocytometer counting chamber. According to the results, the water samples stimulated the algal growth (except station 1); although all sediment samples inhibited the growth of populations, in several grades.

Boyacioglu *et al*. (2012) aimed to assess mutagenicity in the sediment samples collected from Nif Brook by extraction method (solvent extraction v:v:v:1:1:1; chloroform, hexane, acetone) using the same strains of bacteria (without metabolic activation) in another study. Extracts of the sediment samples that were collected from 5 different stations in Nif Brook were assayed in three different concentrations (in 25, 50, 100 µg). Sediment sample from Nif 5 side was observed to be weak-mutagenic and those from Nif 1 and 4 sides were observed to have toxic effects. Toxic effects of the sediment samples on bacteria were observed on the basis of significantly reduced numbers of revertants compared to the solvent controls. According to Ames criteria, sediment samples from the Nif 5 were considered as mutagenic on TA 98 strain.

4. The ecotoxicological studies performed in Aliağa Bay

Aliağa Bay is located in the northern part of Izmir and has been exposed to domestic and industrial wastes. Primer pollutants of the region are sourced by the second major petrol refinery in Turkey that produces row petrol material and fuel-oil. In addition to that, marine transport and shipbreaking in the territory is quite active. Samples of Black Goby (*Gobius niger*), which is an indicator species, were collected to investigate the haematological parameters such as RBC (Red Blood Cells), HGB (Haemoglobin), HCT (Haematocrit), MCV (Mean Cellular Volume), MCH (Mean Cellular Haemoglobin Concentration), PLT (Trombocyte); to determine whether sea water and sediment in Aliağa Bay convenient to live or not (Katalay and Parlak, 2004).

The blood parameters were measured by using standard methods. RBC, HGB and HCT levels of the samples that were collected around Aliağa refinery were observed to be higher than the levels of other samples. On the other hand, the highest MCHC levels were observed in the samples that were collected around Foça. Significant increases were observed in cytoplasmic vacuoles and membrane deformations in erythrocytes, in the samples that were obtained from the inner part of Aliağa Bay (Katalay and Parlak, 2004).

The marine ecosystem in the territory is under influence of industrial activity that includes paper mills and many various industries. As it is important for the ecosystem and human health, a study was performed by carrying out Ames test with *S. Typhimurium* TA98 and TA100 strains, using sediment samples collected from 6 stations, to determine the mutagenic and genotoxic effects of sediment of Aliağa Bay. The results of the study pointed out that the sediment samples collected around the shipbreaking shipyard found to be toxic and weak mutagenicity was detected in the other samples. Consequently, it was reported that Aliağa Bay had hazardously been polluted by the toxic and genotoxic substances released from the shipbreaking facilities (Boyacioglu *et al*., 2014).

Arslan *et al*. (2015) studied on the fish samples obtained from the parts of Aliağa Bay where it was reported to be polluted by the various mutagenic agents; to determine biological damages. For this purpose, micronuclei (MN) test was performed using peripheral erythrocytes and gill cells of different fish specimens caught from both polluted and relatively clean sites from Aliağa Bay. According to the test results, the frequency of MN in the samples that were collected from relatively clean sites was found to be higher than it is referred in ICES (2012) reports. Thus, the region was reported to be polluted by mutagenic/carcinogenic pollutants.

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FISHERIES IMPACTS ON SEA TURTLES IN THE AEGEAN SEA

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1. Introduction

Fossil records of the sea turtles distributed in the oceans and seas go back to 200 million years from today and only 8 species of these are able to sustain their generations (Geldiay, and Koray, 1982) mainly in tropic and subtropics seas. Off 5 species of sea turtles (*Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata, Lepidochelys kempii*) recorded previously in Mediterranean, only *Caretta caretta and Chelonia mydas* nest on the Mediterranean Sea coats (Baran and Kasparek, 1989). Occurrence of *Eretmochelys imbricate* and *Lepidochelys kempii* in Mediterranean basin is very limited. The Mediterranean is an area of rare occurrence for *Eretmochelys imbricata*. Laurent and Lescure (1991) reviewed the seven documented records for the hawksbill in the Mediterranean. There were two captures near Marseille and Albania; two collected close to the southern Sicilian coast, and Malta; and three individuals captured in nets in French coastal waters. Demirayak et al. (2002) reported that in south Lebanon the fishermen interviewed insisted on identifying the Hawksbill turtle (*Eretmochelys imbricata*) from the colored charts. However, this identification should be treated with scientific caution (immature loggerhead turtles may be identified as *Eretmochelys imbricata*). The origin of hawksbills in the Mediterranean has been speculated as either from the Atlantic or the Red Sea. The latter is the most favored hypothesis; as noted by Laurent and Lescure (1991), several hawksbill nesting sites occur on the shores of the Red Sea in Egypt and Sudan (Meylan and Donnelly 1999). The hawksbill is the most abundant sea turtle in the Red Sea (Ross and Barwani 1982).

Similarly, the Mediterranean represents an area of rare occurrence for the Kemp's ridley sea turtle, *Lepidochelys kempii*, though it is known that individuals do make transatlantic crossings (e.g., Fontaine *et al*., 1985). There are only three documented records for this species in the study area: an October 1999 capture off the island of Malta; an October 2001 capture in a gillnet in shallow waters off Santa Pola, Spain (between the island of Tabarca and Guardamar del Seguera); and a July 2001 capture in the Gulf of Lion; and a September 2005 catch at the west of the Strait of Gibralter in the Gulf of Cadiz (Tomás *et al*. 2003; Oliver and Pigno 2005).

Along with that sea turtles have life sustaining risks based on the fishery activities in the world and Mediterranean Sea (Margaritoulis et al., 2009; Casale, 2008; Margaritoulis and Rees, 2011). Therefore, *C. caretta* and *C. mydas* species were included in endangered species list by IUCN Red Data List (Ver. 2015-3) around the world due to their decreasing populations. While *C. caretta* and *C. mydas* that visit southern coats of our country with the aim of nesting and egg laying are frequently seen in the seas of Aegean and Marmara (Geldiay, 1984; Baran et al., 1991; Türkozan and Baran 1995), Dermochelys coriacea, leatherback turtle, has no any egg laying or nesting record along the Turkish coasts, except for only few records of occurrence in Turkish seas (Taskavak et al., 1998; Taskavak and Farkas 1998). Leatherback turtles have been noted in almost every area in the Mediterranean, but available data suggests that it frequents specific areas more, such as the Tyrrhenian and Aegean Seas. The species is present all year round; there is no evidence of seasonality for longitudinal distribution and only possible seasonality for latitudinal distribution (Casale et al., 2003). Most of the observations concern isolated individuals (Camiñas, 1998). The specimens found in the Mediterranean are most likely to be of Atlantic origin. Carapace lengths of stranding and by-catch in the Mediterranean range from 112 to 190 cm (mean 145 cm; Casale et al., 2003). The observed and captured leatherback turtles in the Mediterranean are mainly adults (Camiñas, 2004). Leatherbacks are frequently stranded on the Mediterranean coast (Camiñas, 1998; Lescure et al., 1989). In European drifting longline fishery a total of 23 turtle catch were observed in the Greek monitoring program (22 loggerhead *Caretta caretta* and one leatherback *Dermochelys coriacea*), and 2127 turtle catch in the Spanish one (2125 loggerheads and two leatherbacks). In 2003, Casale et al. (2003) reviewed a total of records (stranded: 52, taken: 9, captured: 170, sighted: 53 and unknown circumstance: 127) for the whole of the Mediterranean basin. Although it prefers a diet which is rarely based on fish (Bjorndal and Musick, 1997), the leatherback turtle appears to be the species most affected by longline fisheries (Ogren, 1994; Gerrior, 1996). The rare captures reported for the Mediterranean (De Metrio et al., 1983; Crespo et al., 1988) suggest that the density of this species is so low in this sea that the likelihood of surface longline hooks meeting a *Dermochelys coriacea* is almost nil (Gerosa and Casale 1999). Comparisons between longline catch rates in the Mediterranean (Casale et al., 2003) and Atlantic show that the Atlantic catch rate is 54 times higher, which suggests that the occurrence of this species in the Mediterranean is much lower than in the Atlantic.

As stated above, the most important aspect that threatens sea turtle populations at the marine environment is fishery activities. There are numerous records concerning to that sea turtles are mostly get caught by trawling nets, or seine nets or long line fishing as dead or alive (Chana, 1988; Poiner and Harris, 1996; Robin 1995; Alessandro and Antonello,2010; Margaritoulis and Rees, 2011; Corsini - Foka *et al*., 2013). Yerli and Demirayak (1996) and Taşkavak and Atabey (2001) gave striking clues concerning to status of turtles affected by fishery activities along the fishery season in their field studies that they made with certain number of trawler boats in the eastern Mediterranean (Taşkavak *et al*., 2003). But even if it does not seem possible to detect number of the sea turtles that are accidentally caught, it is emphasized that more than 35.000 *C. caretta* are under this risk in Mediterranean (Panou *et al*., 1992). Mediterranean is a very old fishery area. Aegean Sea that protects its place within Mediterranean includes important fishery areas in terms of diversity and density for both pelagic and demersal fish species due to that its continental shelf includes rugged and wide planes, and also forms migration ways of the fishes. The sea turtles that have an instinct for catching the fishes caught by nets and fishing lines necessarily enter these fishery areas for taking nourishment. For example; number of sea turtles affected by fishery activities around Rhodes Island (Aegean Sea) is very remarkable (Corsini-Foka *et al*., 2013). The ratio of Aegean Sea in the Turkish fishery is 10,2% (TUIK, 2013). Along with that an important part of the fishery activities has been carried out in the Çanakkale coasts and even if number of dead sea turtles (strandings) seen on the shores shows that sea turtles select this region as a living space, there are very limited studies concerning to utilization of this region by turtles (Yalçın-Özdilek *et al*., 2008; Akdeniz *et al*., 2012). Along with that the fishing operation carried out in our coats varies in accordance with the equipment used in the fishery, it is reported that a large number of sea turtles are caught by fishing nets or fishing lines. The first official detection among these were the cases at which were seen in the field studies in 1994 and sea turtles beheaded with the aim of casting a fishery lines were detected (Yerli *et al*., 1996). At the next stage of this study (cooperation with regional fishermen), it was indicated that number of the turtles affected from fishing activities along a fishery period (September-May) was detected as 10-150. (Yerli *et al*., 1996). In fact, fishing the sea turtles is not permitted in our country. Internal conventions such as Bern and Barcelona and national legislations such as 6th Article of Water Products Circular published by Ministry of Agriculture are the main measures to protect these species. But it is a reality that number of accidentally caught turtles is still very high for these species of which populations have been decreasing.

Total number of the accidentally caught turtles in Izmir gulf and its environs (Aegean Sea) between the years of 1995 and 2001 was 127 (101 units *C. caretta*, 25 units *C. mydas*, 1 unit *D. coriacea*) and this is a very high number (Taşkavak *et al*., 2003), despite being away from nesting beaches.

Similarly, it is another important finding that a total of 17 (*C. caretta*) turtles as dead and alive in only Izmir Gulf were seen within 1 year between April 2002 and August 2003 (Taşkavak *et al*., 2003) (Figure 1). It is understood that this shows a little different development in northern part of Aegean Sea, Çanakkale coats, especially around Bozcaada. 49% of the caught turtles were the alive young turtles that were caught by fishing equipment. Frequently seeing the sea turtles in the fishery areas especially in the summer months may suggest to us that young turtles visit to these fields with the aim of feeding (Akdeniz *et al*., 2012).

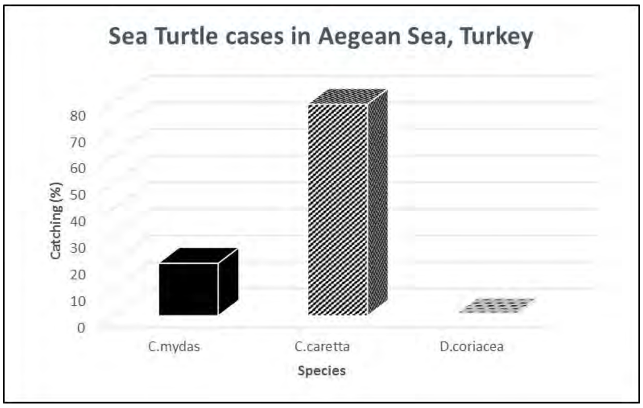

Figure 1. Sea turtle cases detected at Izmir Gulf and its surrounding (%)

Result of the study done around Rhodes Island between the years of 1984 and 2011 revealed that total 194 sea turtles (152 units *C. caretta*, 42 units *C. mydas*) were seriously affected by trawl operations (Corsini-Foka *et al*., 2013).

At Table 1, the sea turtles caught at the Greek and Turkey coasts in Aegean Sea were given according to which fishing operation and their health statuses. According to Margaritoulis and Rees (2011), ratio of accidentally caught turtle is 7 of 17 turtle and is given as 57.1% at Aegean coats depending on the fishing operations.

According to Broderick *et al*. (2002), 2280-2787 *Caretta caretta* and 339-360 *Chelonia mydas* individuals nest on the overall Mediterranean beaches in a yearly period. Kasparek *et al*. (2001) estimated that the entire annual average nest for *C. mydas* in the Mediterranean is between 350-1750 made by 115-580 adult individuals. Turkozan *et al*. (2003) claimed that *C. caretta* make an annual average of 1267 nests on 20 beaches (primary, secondary and tertiary importance of nests together) in Turkey (Figure 2). Off 20 beaches, the Ekincik and Dalyan beaches of Aegean coasts of Turkey have about 10-15 and 220-250 nests, respectively, and average of 700 hatchlings reach sea at Ekincik in 2004. The average number of arrivals on the Dalyan beach, one of the best observed, investigated and protected beach of Turkey, is about 8500 and 10500 in 2004 and 2005, respectively. In Ekincik, ratios of unfertilized eggs, dead embryos and abnormal eggs are 11.6, 13.9 and 0.5, respectively. Ratios of hatchlings, hatchlings reaching the sea and depredated or being trapped hatchlings are 74.0, 95.7 and 4.3. Regarding natural hatching success and survival on Dalyan beach; ratios of unfertilized eggs, dead embryos and abnormal eggs are 4.4, 11.3 and 0.1, respectively. Ratios of hatchlings, hatchlings reaching the sea and depredated or being trapped hatchlings are respectively 56.8, 92.1 and 7.9. More recently, in 2011 and 2012, some nesting and hatchling events were occurred on the beaches of Davutlar (Kuşadası-Aydın) and Kabakum (Dikili-İzmir).

Figure 2. Nesting areas of sea turtles in coasts of Turkey (Yerli and Demirayak, 1996).

Sea turtles migrate in the first months of the year for nesting, feeding or wintering from the Atlantic to the West Mediterranean or in the opposite direction. Migration routes of the juvenile sea turtles in and out of the Mediterranean basin were seen in Figure 3. *C. caretta* frequently seen in the Turkish and Greek coasts and accidentally caught marine turtle numbers by fishermen shows that Aegean Sea is one of the most important migration routes in the Mediterranean basin (Margaritoulis and Rees 2011; Akdeniz *et al*., 2012; Hays *et al*., 2015).

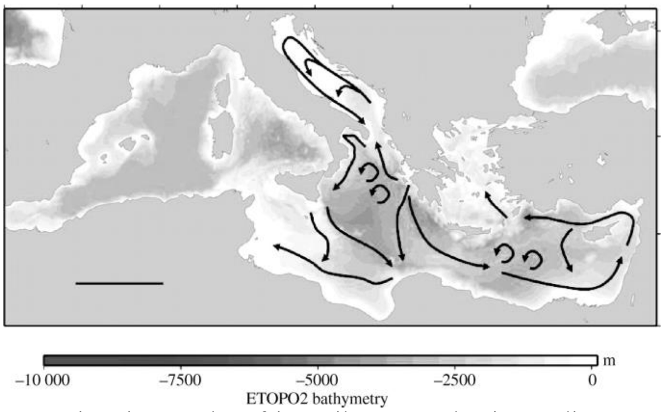

Figure 3. Migration tracks of juvenile sea turtles in Mediterranean (Hays *et al*., 2010).

Table 1. Records of sea turtles caught in Aegean Sea (Margaritoulis and Rees, 2011)

ID	LAST NESTING	LOCATION OF TAG RECOVERY	DATE OF RECOVERY	DAYS ELAPSED	METHOD OF RECOVERY		REMARKS
H3410	12/07/1992	Gulf of Gabes Tunisia	3/10/1992	83	Stranded	D	No external injuries
P4937	26/06/1994	Bodrum Turkey, Aegean Sea	10/9/1994	76	Tag found	?	Second tag (plastic A282) found at bottom
Y5587	04/08/1995	Gulf of Gabes Tunisia	20/3/1996	229	Captured	?	Date of letter (not capture)
Y5592	19/06/1995	Spetes Isl. Greece, Aegean Sea	30/8/1996	438	Stranded	D	Fully decomposed. Broken shell
H657	16/06/1997	Offshore Ayvalık, Turkey Aegean Sea	1/11/1991	868	Floating	D	Injury on front left flipper
E989	12/07/1999	Aegina Isl. Greece, Aegean Sea	17/11/1999	128	Stranded	D	A large part of Shell was missing
E978	17/06/2000	Lesbos Isl. Greece, Aegean Sea	28/4/2001	315	Stranded	D	Parts of fishing net on flippers
E982	25/07/2000	Offshore Nahariya Israel	23/2/2002	578	Floating	D	Fully decomposed, longline hook
E991*	19/07/2001	Heraklion (harbor) Crete Isl.	15/5/2002	300	Floating	D	Injured on eye and carapace
E803	27/06/2000	İzmir Turkey, Aegean Sea	19/8/202	783	Stranded	D	Death estimated about 10 day ago
C6805	18/07/2003	Gulf of Gabes area	16/11/2003	121	Caught/released	A	By Italian trawler based in Lampedusa Isl.
E936*	11/07/2001	Gournes Crete Isl.	1/2/2004	935	Stranded	D	Fully decomposed
RE175	24/07/2004	Karystos, Greece Aegean sea	4/8/2004	11	Stranded	D	Recent propeller injuries.
E962	17/07/2003	Naxos Isl. Greece Aegean Sea	22/5/2005	675	Stranded	D	Heavy injury on carapace left side.
E999*	20/07/2005	Retymno Crete Isl.	8/8/2005	19	Stranded	D	Right eye swollen
A682	20/07/2004	Gulf of Trieste, Slovenia	9/8/2005	385	Floating	D	Caught in stationary gillnet
RE220	15/07/2004	Zarat Gulf of Gibes Tunisia	5/12/2006	873	Stranded	D	

Turtle Deaths Depending on Fishery Operations

The belief of the community in terms of adult and eggs treats some diseases lies behind the basis of sea turtle hunting or collection in our country between the dates of 1950 and 1970 (Yerli *et al.*, 1996) (Figure 4). But within the process following 1973, hunting of these reptiles was forbidden and these species were taken under control as stated at Water Products code no 1380 and circular.

Figure 4. Marine turtle hunting (Hamid, 2014)

All nets used in the fishery are a system that makes direct nutrition attractive for sea turtles and increase the turtle catching and turtle mortality (Panou *et al.*, 1992; Gerosa and Casale 1999). The ones that have caused death of these animals directly among the fishing equipment are: fishing lines (longline fishing lines), trawling and seine net operations, tuna fish baits and gillnets (Argano and Baldari 1983; De Metrio *et al*., 1983; Laurent 1991; Argona *et al*., 1992; Godley *et al*., 1998).

Longline Fishing; catching with fish line is frequently seen among mature fishes whose lengths are more than 50 cm (Gerosa and Casale, 1999) (Figure 5). As a result of this caught, also injuries due to the hooks attached their mouths during swallowing the fishing feed at the fishing line (Figure 6). At the report no FAO 738, it is understood that 50 *C. caretta* specie sea turtle were caught with this method in a year in Aegean Sea of Greece (in Panou *et al.*, 1992) but direct death ratio was not detected (Camińas, 2004).

According to Casale (2008), more than 50,000 individual were caught with longline fishery at Spain, Morocco, Italy, Greece, Malta and Libya waters in a year with death ratio of 40%. Main reason of less turtle that were caught in the Greece waters, Aegean Sea, was given as the variations at yearly by-catch data (Alessandro and Antonello 2010).

Figure 5. Marine turtles under heavy fishery impact (Page, 2012).

Figure 6. *Caretta caretta* with a hook in her mouth

Trawling; these fishing tool generally catch the individuals whose lengths were more than 40 cm. The main danger of this net are drowning depending on long drawing period of the trawling operations and shell damages depending on the drop of the trawler bag during emptying to the deck (Taşkavak *et al*., 2003) (Figure 7).

At FAO report, the death ratio of sea turtles caught in bottom trawlers in the Greece waters was 2,6% (Margaritoulis *et al.*, 1992). It was stated that effect of trawler operations on accidentally caught turtles at the Greece waters was low (Alessandro and Antonello 2010) but there was no exact information concerning to how many turtles were caught in a year. At the data revised 7 years after this research (Panou *et al*., 1999), it is understood that 80 units' turtles were caught by trawlers in a year. At the report, it was seen that fishery activities at Aegean coasts of Turkey has an important effect on turtle deaths and these deaths were 0,5%. It was stated that annual catching amount at bottom trawlers was 809 (Oruç *et al*., 1997). The juvenile turtles caught by bottom trawlers in Western Mediterranean were at the rate of 81% (Oruç, 2001). Besides that, it is important that 200 units turtles are caught annually in artisanal fishery which not having a commercial dimension (Godley *et al*., 1998).

The Precautions Preventing Catching the Turtles

The fishery activities done at Mediterranean waters create an incredible pressure on regional stocks of the turtles. Because Mediterranean basin is used by various sea turtle populations as feeding, wintering and most importantly nesting and egging areas. Every year more than 60 000 turtles are affected from fishery activities and shows death ratios changing between 10-50%. For extinguishing or minimizing these catches, national and international legal regulations were brought into force. But measures taken to protect marine turtles in seas are not as effectives as the precautions to protect them on the land where they use nesting and egg laying.

With this aim, TED (Turtle Excluder Device) developed and applied in USA for the first time at trawler net models for decreasing turtle deaths and achieved its aim (Mitchell *et al*., 1995; Ogren *et al.*, 1977; De Metrio *et al.*, 1983) (Figure 8).

When ratio of the sea turtles caught in Turkey is taken into consideration, feasibility of TED model that may be adapted to traditional trawler nets used especially at shrimp fishery was carried out by Atabey (1999) for the first time. With this study, it was stated that Super Shooter grill model (Figure 9) is a model of which adaptability to the shrimp nets used especially in Eastern Mediterranean is high, cost is low, usage is simple and that maintains the turtles outside during fishing composition (Atabey and Taşkavak 2001; Taskavak and Atabey 2001). According to Alessandro and Antonello (2010); by departing out the sample of the countries that first tried TED grill system was tried, it was emphasized that determining type of TED grill model to be applied to the trawlers by taking regional and timewise measurements in to consideration may be an example for other countries.

Figure 7. A marine turtle caught with fishing net

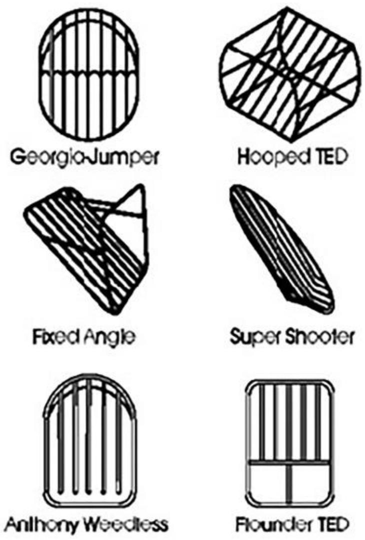

Figure 8. Various TED Models

Our country that carry out 10,2% of its annual fish production from Aegean Sea obtain product in Aegean Sea with Greece by coastal fishery. In this sea that is open to fishing at such an extent, detection of the sea turtles that visit Aegean coasts with the aim of reproduction and nutrition from time to time by fishers and researchers of both of these countries holds a probative qualification for turtle deaths. There is a need for detailed studies concerning to rearrangement of fishery limitations and net equipment by detecting migration ways of sea turtles within Aegean Sea coast of Turkey. Therefore accidentally marine turtle caught in the Turkish coasts of Aegean Sea as well as individual deaths and injuries may be prevented.

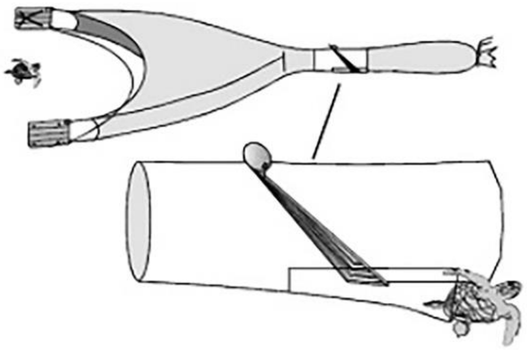

Figure 9. Trawl net equipped with TED grids and its working principle.

In order to heal injured turtles, The Sea Turtle Rescue Center (DEKAMER) was established by Pamukkale University in 2009 in Dalyan, Muğla. After treatment of injured turtles, they release them back to their natural habitats. Tracking injured turtles after their rehabilitation as well as healthy turtles after their nesting was also carried out in DEKAMER to determine the migration routes. Additionally, they help educate the public about conservation efforts. Similarly, Sea Turtle Research and Application Center (DEKUM) was established by Onsekiz Mart University in Çanakkale. Their studies are mainly focused on the conservation and monitoring studies in Samandağ beach, Antakya.

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AN OVERVIEW OF THE ARTIFICIAL REEFS ALONG THE AEGEAN COASTS OF TURKEY

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1. Introduction

According to Seaman and Jensen (2000), "An artificial reef is one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological, or socioeconomic processes related to living marine resources". Following this description, planned artificial reef deployments and applications can be traced back to Japan whom have been applying artificial reefs for more than 60 years (Çakaloz, 2007). USA and Japan being the leading artificial reef applyers, Turkey has been placing artificial reefs for 30 years. Ranging from the concrete water pipes that have been placed in the Urla bay area in 1983, or the 10 trolleybuses that were placed in 1989, of all these applications the first real planned scientific work was conducted in 1991 near the shores of Hekim Island (Lök, 2002).

Following this first scientific research, local fishermen, fisheries cooperatives and local governances soon started placing their own artificial reefs in their own fishing zones. Every following new artificial reef led to new research, which again led to new artificial reefs. The increase in projects required better regulations to be set up. The Ministry of Agriculture and Rural Affairs prepared "guidelines for artificial reef application" and immediately enforced this. In the past 25 years, more than 30 projects were prepared and most of these were realized.

The Aegean Sea, being the first sea in Turkey to be home to artificial reefs, also is the leading region where most researches are conducted and also holds the most artificial reefs. Also very well known for its shore fishing and scuba diving regions. Both of these are greatly interested in artificial reefs, and are strong stakeholders. When we look at the applications of artificial reefs, we can see that there are 3 different reasons for these applications. Namely; 1) Prevention of illegal trawling, 2) supporting small scale fishing, sport fishing and also scuba diving, 3) Protection of the sensitive Posidonia meadows and the breeding grounds. Support for these types of artificial reefs come from Fisheries cooperatives supporting said small scale fishing reefs, and local scuba administrations supporting the reefs for scuba purposes.

The artificial reef applications in the Aegean Sea are mostly done in bay areas. In this paper we will go over the partially or fully completed artificial reefs ranging from the Northern Aegean region, down to the Southern Aegean region (Figure 1)

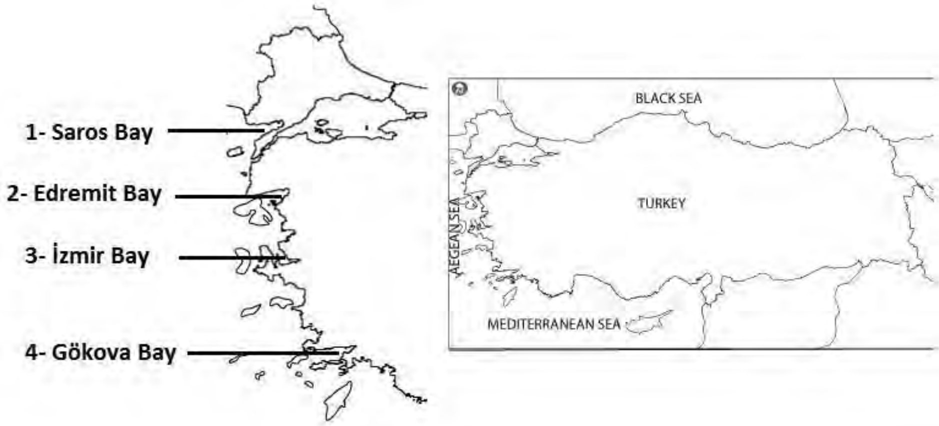

Figure 1. Artificial Reefs Sites at Aegean Coast of Turkey (map modified from www. mapsofworld.com)

1. **Artificial Reefs at Saros Bay**

Found at the most northern part of the Aegean Sea, the Saros artificial reef is also the first underwater history museum. Placed at the Mecidiye shore of the Keşan district of the Edirne region, it is made up of different reefs for different purposes (Lök and Metin, 2006). Starting in 2010, the project was finished in 4 years time and now serves some purposes:

i. The support of small scale fisheries. The bay being protected against trawling is home to 2 different cooperatives with a total of 55 members. Gillnets and longline fishing are the most used methods. During the summer season, an increase in sport fishing can be seen. But due to the seabed being sandy and the low number of reefs minimizes the number of fishing grounds. Adding to this, the amount of fish farms, and military zones makes the already low numbers of reefs, smaller in size (Tokaç *et al*., 2010). Therefore, by adding more artificial reefs, small fisheries, and sport fishers is supported (Lök *et al.*, 2009)

ii. By create an underwater history museum, scuba diving is supported. The bay, holding 5 scuba diving schools, is one of the most sought after diving regions visited by said schools and also many scuba diving schools from the Istanbul and Çanakkale region. The great National and International historical importance of Gelibolu was therefore one of the reasons to form an underwater museum that would represent Gelibolu Peninsula, and perhaps bring a different approach to the annual memorial events.

iii. Support and protection of the marine biodiversity. By increasing the numbers of dive and sport fishing locations, the strain put on the natural and most used territories was lowered.

iv.

During the application, 1 m^3 hollow cement blocks were placed to protect marine biyodiversity, for scuba purposes a 42m naval attack boat, and for historical representation 12 statues and reliefs were placed.

In this artificial reef site only one scientific research has been conducted up untill today. Altınağaç et al. (2013) have tried to put forth the monthly fish species that can be found in this region. With a depth ranging from 18 to 27 m with a total amount of 400 blocks used to create this artificial reef, 37 different fish species were spotted. The red mullet (*Mulus barbatus*), two-banded bream (*Diplodus vulgaris*), picarel (*Spicara maena*) and black bream (*Spondyliosoma cantharus*), were recorded as the most abundant species around the artificial reefs.

2) Artifical Reefs at the Edremit Bay

The increase of importance of the Edremit bay came after the 2011-2012 artificial reef projects. The National Master Plan that was prepared for artificial reef applications brought with it the realization of the biggest artificial reef of the Mediterranean Sea. With the purpose of support small scale fisheries, prevention of illegal fishing and protection of ecological values, a shore line of 15 miles from Küçükkuyu to Akçay was used for this project. In this project a total of 6540 concrete reef blocks, 240 anti-trawl blocks were used. 7 sets placed at 7 different locations helped support small fisheries. Fisheries cooperatives with a total amount of 89 members that were settled at Küçükkuyu and Altınoluk made use of these locations (Pelister, 2015).

Each reef sets made up from 30 blocks were placed at 0,5-1 mile from the shore line. The depth is approximately 20-30 meters. The seabed is mostly made up of mud and / or coarse sand. The height of each cluster does not exceed 6 meters.

During the first application of the National Master Plan, after the first deployments monitoringe and scientific research started right away. After 3 months to a year after the first deployment, a research for bluefish fisheries was conducted using trolling, and the total catches were compared from year. The amount of bluefish caught by the Altınoluk cooperative increased by a five-foldin a year. And results shows the length of each fish was found to be around 28-39cm, which is above the minimum length requirements of 20cm (Gül, 2013).

In a different study t small scale fishing methods (long line, trolling, rod fishing, gillnet) and underwater counting methods were used. This study was conducted over a 1 year period by sampling the region monthly. In the artificial reef regions a total of 61 teleost fish species from 28 different families, a total of 5 cartilaginous species from 3 different families, 6 species of molluscs from 5 different families, 4 cephalopod species from 4 different families, and 2 echinodermata species from 1 families were recorded. 84,6% of these species have economic importance. The dominant ones being; Sparidae with a total of 14 species, the *Diplodus annularis* for abundane (10%), and the *Pomatomus saltatrix* for biomass (30%) (Pelister, 2014). A project led by TUBITAK (Project # 112O383) tried to understand the movement of the fish around the artificial reefs by using telemetric methods. Side fidelity and homing behaviour of *Pomatomus saltatrix*, *Diplodus vulgaris, Diplodus puntazzo, Sparus aurata, Sciaena umbra, Scorpaena porcus,* and *Scorpaena scrofa* are subjects that are still being researched (Lök and Özgül, 2015; Özgül, 2015a; Özgül, 2015b). The main research reasons are to understand the connection of fish and reef, and to support fishing and provide better management thereof.

The region was also subject to socio-economic research. Tunca *et al.* (2014) have conducted surveys regarding the placement of the reefs to understand the expectations, and the situation after placement of said reefs. The survey was conducted with commercial fishermen, recreational fishermen, and local residents. The stakeholders were positive about the reefs. The increase in the amount of days where recreational and commercial fishing was conducted also showed us that there was a positive increase in this region (158%, and 31% respectively).

The application of the Edremit project ended in 2013 with a total of 7 clusters. Being the first application of the National Master Plan for artificial reefs, it is however not part of a management plan. The only limitation that was put in place was to close certain sets for fishing, and periodicly changing which set is going to be closed for fishing. The sets that are closed for fishing are announced periodicaly to the fishermanss by the notifications. Due to being the first application of the National Master Plan for artificial reefs, research and monitoring studies performed in these sets are also widely supported. The results obtained by the conducted research and surveillance is of great importance for setting up management plans, and to shine light on future applications.

3) Artificial Reefs at the Izmir Bay

The artificial reef applications that started in Izmir were the precursors for all artificial reef applications in Turkey. In 1983 a French scientist that was on temporary duty at the Ege University Hydrobiology Research Center started artificial reef projects by deploy concrete pipes (Lök, 1995). In 1989, a cooperation between the local governance and the University saw that 10 trolleybuses were deployed into the Izmir bay. The depth of this application being 16-20m, saw no further research and surveillance thus leading to no information on this application.

However, in 1992 the first planned and scientific artificial reef project was started in Urla around Hekim Island (Lök, 1995). As a doctorate thesis, this scientific research that was conducted saw an artificial reef dropped at depths of 9 and 18 meters. Before, during and 8 years after the drop of this artificial reef, research and monitoring was conducted at and around these sets (Lök ve Gül, 2005). Solely being a scientific research, when the first reports came in of this application at the same time Dokuz Eylül University dropped plus shaped concrete reefs in the Foça region. However, no scientific research was conducted on the project in Foça, where 20 blocks were dropped at 17m.

In 1995 the first ever Turkish artificial reef project aimed at fishery was started. To support small fisheries, to prevent trawling and to protect the ecosystem, the project was planned to consist of 100 (50 cubic, 50 plus shaped) concrete blocks which would be placed at 21 meter depth in Çeşme Dalyanköy. The studies conducted in this region were to observe and report the fish species. Gül and Lök (2007) stıdied monthly for 2 years by diving to said sets and by visual census. After the conducted research the region was found to consist of 35 species from 13 familiae. Lök *et al*. (2008) have tried to observe and record the differences of species throughout a day. During 4 different periods, namely morning (06:00-07:00), noon (12:00-13:00), afternoon (18:00-19:00) and night (00:00-01:00) dives were conducted and the species, abundance, and approximate biomass were recorded. In both sets, the Sparidae and Labridae familiae were found to be dominant. Again, in said region, *Chromis chromis* and *Spicara maena* were found to school and were found to contain the most individuals. During fishing research by using rods, 7 species were caught (Aydın *et al*., 2008). Among the species caught, *Diplodus annularis, Boops boops, Spicara maena* and *Serranus scriba* were recorded to be caught the most. The Dalyanköy artificial reef is known to be used by the Dalyanköy Fishery Cooperative for fishing purposes. In a different artificial reef project approved by the local governor of Çeşme, the Dalyanköy reef region was made larger in size. Alongside this, certain objects were also added to support local scuba diving tourism.

In a cooperation between the Izmir Municipality and Dokuz Eylül University in 2006, an artificial reef was placed at the Özbek shores. With no scientific report on said artificial reef, certain pictures taken of this application can be found in the archives.

In the near past, a different scientific project to understand and design specifically for certain species was started. Urla bay was used for this project, and for this purpose in 1999 30 blocks (16 holed) of octo-reefs (Ulaş, 2000), and in 2005 80 blocks (4 holed) of octo-reefs were placed (Tokaç *et al*., 2010). After observing and recording 168 natural nests, the octo-reef design was improved. Over a period of 2 years of sampling, the population was found to increase in the artificial nests (Ulaş, 2009). Again, in the same reef, a research that was started in 2014 has tried to correlate size, depth and seabed types with prefered nests (Ulaş *et al*., 2015).

Mordoğan artificial reef application began at 2006. AT the shores of Mordoğan are made up of rocky shore lines. With seal nests, some zones were banned from fishing. To compensate aggrieved fishers, and to increase recreational fishing, Mordoğan municipality and “360 Derece Tarih Araştırmaları Derneği” (360 degrees Historical Research Association) cooperated and set up an artificial reef project (Lök and Metin, 2006). As materials for the reef, 250 units of 1 m^3 hollow cubes were found to be fitting. Eventhough not taking place in the original planning, 1 bomber plane and the reproduction of a historical ship were also deployed to be used as artificial reefs. Most of the concrete slabs and concrete blocks have been placed as of today. Eventhough no official research has been conducted on these artificial reefs, fishermanss in the region have stated that they do use these reef zones to fish.

Izmir bay, is the first region in Turkey were artificial reefs were used. With experts in the field of artificial reefs, Ege University Faculty of Fisheries still works hard untill today to research, monitore and record in this region. The same team is also responsible for more research and monitoring on different reefs in the Aegean Sea.

4) Artificial Reefs at the Kuşadası Bay

The first artificial reef project to be realized in the Kuşadası region were in 1998 on the Gümüldür and Ürkmez shores. This project was realized by cooperation by local governance and University. The local fishery is limited by the small amount of small scale commercial fishers and recreational fishers. There is no fishery cooperative. The reason these reefs were set up is to increase recreational and small scale fishing, and to prevent illegal trawling. Consisting of 10 sets of each 18 blocks (2 m^3) in Ürkmez and 12 clusters of each 20 blocks (1,7 m^3) in Gümüldür. All sets in both regions are made of concrete hollow blocks and are placed at 800-1000 m. distance of the shore (Gül, 2008).

An monitoring study is not foreseen for these reefs. But during the years 2004-2006 a TUBITAK backed project (project# 103T020) took place in this region and a doctorate thesis of this study is available (Gül, 2008). After observing the different species available at said reefs; the presence of said reefs, the type of surrounding substrate and the different designs has shown the effect on what kind of seasonal difference in species occur. Monthly visual counts have shown us that a total of 58 species from 21 different familiae are present. It has show us that most predominant familiae are the Labridae, Sparidae, Serranidae, and the most predominant species being *Chromis chromis*. 50% of the species recorded are of commercial value. 34 species of the 58 recorded at the reef were never recorded anywhere along the shore line in control zones. Comparison of the sea floor has shown us that reefs placed on seagrass meadows

(20 families, 51 species) showed Labridae, whereas reefs placed on muddy area (15 families, 43 species) did not show any sign of this familia whatsoever. Diel research have shown that during the 4 periods of the day, during the morning biodiversity was the greatest, and from noon to afternoon species and fish abundance were the highest. Comparison of design has shown us that cubic blocks cause greater school formations of Sparidae family, *Seriola dumerilii, Spicara maena*, and *Chromis chromis*. The research has shown us also that around the reefs *Loligo vulgaris* and *Sepia officinalis* were spotted and that *Scyllarides* sp. individuals would hollow out nest underneath the blocks.

In a different research conducted in this region, a comparison was made for different depths for reefs and the different types of species that will visit said reefs (Çakaloz, 2007). The reefs on the Gümüldür shores which were placed at depths of 20, 30 and 40 meters were subject to research for 2 years. During this research, the findings were recorded and from this we were able to compare depth with fish community and found that depth does affect the fish communities and the composition thereof especially after 30 meters of depth a greater difference was spotted in amount of fish species and their biomass (Gül *et al*., 2011).

Also, in the same region a floating reef research was conducted. During this doctorate research thesis, the main purpose was to understand how this technology could be used for pelagic hunting (Özgül, 2010) two fish aggregation devices were deployed at Gümüldür. Data was gathered via fishing operations (pelagic long line, trolling, gill nets, fish hooks, and fish traps) and underwater visual counting methods. After a 2 year sampling period, 29 fish species of 18 different familiae were recorded. FAD-50, which were deployed at 50m depth, showed higher counts than FAD-100 which were deployed at 100m. However, the FAD-100 biomass was far higher than FAD-50. This work has showed that pelagic long line fishing gave higher yields, and that the yield was especially high during the spring. The region is mostly used by recreational fishers and purse seiners.

Another reef in the bay area was placed along the Pamucak shore. This project was realized at 2002 by the local governance to prevent illegal trawling in the area. In areas where there is no fishers harbour, it is seen that there are more recreational and small scale fishers. The project was therefore very suitable because it supported small scale and recreational fishing, prevented trawling, and protected juvenils giving them a chance to feed and grow safely. Along the 9 km shoreline, 470 blocks where dropped. On both ends of the shore line, sets consisting of 146 blocks were placed and in between these clusters single blocks were placed in 3 lines to prevent trawling activities. In this project each reef block had a volume of 1,7 m^3 and the total volume of the project was 800 m^3. After the deployment of the reef, scientific observations were not conducted. 11 familiese consisting of a total of 19 species were found in the region just in 3 sampling (during deployment, after 1 and 2 years.) (Gül and Lök, 2004). Eventhough there is no fishery cooperative set up in this region, we have found out by asking local fishers and recreational fishers that the artificial reef sets are in fact used for small scale and recreational fishing.

Also, an artificial reef project was prepared in the Kuşadası area by the Kuşadası Rotary club. The project that aimed to support small scale fishery, recreational fishing, and scuba diving was unfortunately never finished. Besides the 10 hollow cubic blocks of each 1,7 m^3 the rest of the project was never put to practice.

5) Artificial Reefs at the Gökova Bay and Marmaris

Bodrum artificial reef project was realized by the Bodrum Sualtı Derneği (Bodrum Marine Association) in 2007. There are 21 active diving centers in the region. With an annual 40.000 touristic and recreational divers potential visiting the region. The project was aimed at taking the load of the natural reefs and shifting this to the artificial reefs to protect the biodiversity and to increase dive locations. Donations from the Turkish Naval Forces in form of a 37m long boat designated "PINAR 1", Turkish Coast Guard Command in form of a 30m long patrol boat designated "SG115" and a Dakota C47 type air craft were sunken at recreational diving depths.

To understand whether or not the project really reached its goal, Cerim (2011) as a Masters thesis has conducted research in this region. Doing survey on scuba diving tourists visiting the region it was recorded that 54% were Turkish, and the rest were foreigners. All information concerning demographics and dive profiles were recorded. What was also recorded was that the tourists were very happy with the reefs and had an understanding concerning the reasons for artificial reefs and what it brought with it. Lök *et al*. (2010) put forth a research on wrecks following a 2 year research on fish species in and around the wrecks. During the research visual counting methods were used and 22 species from 12 different families were found in and around the wreck.

Project also consist of concrete pipes (each cluster consisting of 50 pipes) with radians of 30cm and 60cm were placed at natural rock formations, and also 250 clay jugs were placed at open areas. With this the aim was to increase the hunting zones for small scale fishermans and recreational fisherman (Lök and Metin, 2007). But there is no further information available on these artificial reefs.

The southest project at The Aegean Sea coast of Turkey was prepared at Marmaris. Cooperation between local governance and the local fishery cooperative made way for a project to place an artificial reef in the inner harbour territory to 1) increase recreational fishing, 2) increase the amount of dive locations for recreational scuba diving, 3) provide shelter for younger fishes. In the outer harbour territory the aim was to 1) prevent illegal trawling, 2) protect sea meadows (Lök *et al*., 2000). In said project aim was to use 2070 hollow blocks of each 1,7 m^3 volume but unfortunately the project was only realized partially. In the inner harbour territory only 100 blocks were deployed and the rest were unfortunately also never realized. There has been no research and observation conducted in this region.

2. Legal Regulations and The National Master Artificial Reef Program

In the past, there were no legal regulations concerning planning artificial reef projects. Informing the Ministry of Agricultura and Rural Affair prior to application was enough to recieve an approval. As of October 1999, after meeting stakeholders in a meeting a month prior, it became clear that a regulation needed to be set up and from this the "artificial reef application and desing" regulations came forth. During the preparations recommendations were listened to and rules were set up for the planning and realization of artificial reef projects. Said regulations are still being used and consist of 6 topics which are as follows; 1) description, 2) procedures, 3) objectives, 4) site selection criteria, 5) construction materials, 6) design. Eventhough still not perfect, these guidelines are a great way of regulating the applications and realizations of artificial reefs (Lök, 2002).

The Ministry of Agriculture and Rural Affair decided to prepare a National Master Artificial Reef Program in 2008 to support small scale fisheries, and to protect the marine biodiversity. The potential aritificial reef regions were discussed during this program according to the following objectives;
-Creation of new fishing regions / zones in the less productive regions to promote small scale fishing.
-Conservation of biodiversity

For this program 10 different regions / provinces were selected (of which 3 in the Black sea, 4 in the Aegean sea, and 3 in the Mediterranean sea) where this program would be realized. The National Master Program will be concluded in the year of 2020. Altınoluk artificial reef being the first application of this program is one of the more closely observed regions, and reports from this artificial reef will surely be of great importance for planning of future projects (Lök *et al.*, 2009)

3. Overview

Aegean Sea Artificial Reefs show that the species and families do not greatly change from north to south. Basically, artificial reef projects are used to support and increase small scale fisheries, and to prevent illegal trawling. In the past few years however, supporting and increasing recreational scuba diving zones has become one of the reason too. Eventhoough having recieved an approval from the Ministry of

Agriculture and Rural Affair, certain projects unfortunately never were finished or realized at all. Reason for this is generally lack of funding, or management changes. These projects that were to cover greater areas which were unfortunately never finished, are also preventing other projects from realizing in those specific regions due to not being able to recieve approval for the project due to these incomplete approved projects. To prevent problems like these from occuring any further, it is recommended to only hand out approvals for a certain amount of time to finish the project, and under strict order to have observations conducted for at least 2 years. One of the also very important issues related with artificial reefs in our country is that the effort to set up an artificial reef is great, and the amount of properly trained personal to commence research is only small. With the National Master Artificial Reef Program it seems that this problem may come to an end, and that the future of artificial reef research in Turkey could increase. However, this can only be decided following results of preliminary studies and scientific research on said artificial reefs.

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ENDANGERED SPECIES OF THE AEGEAN SEA

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1. Introduction

The Mediterranean Sea basin is recognized as one of the most important biodiversity areas, where the extended Aegean and Levantine coastlines of Turkey were included to globally defined 25 hotspots (Myers *et al*., 2000). Despite of the lack of knowledge on several marine taxa, a modest biodiversity estimate indicates the presence of at least 17000 species non-uniformly scattered throughout the Mediterranean, in which the highest number of Red List (critically endangered, endangered and vulnerable) species are concentrated at the western shelves, Adriatic and Aegean Seas (Coll *et al*., 2010). A breakdown of the major threats to several faunal taxa (see Cuttelod *et al*., 2008) revealed the loss, fragmentation and degradation of habitats as a direct or indirect result of human activities is the main threat to Mediterranean species, followed by pollution, overexploitation (unsustainable harvesting, hunting and fishing), natural disasters, invasive alien species, human disturbance, and bycatch, respectively in order of importance.

The first law on species conservation, namely the Hunting Law, in Turkey's history was put into force by 1937, during the presidency of Mustafa Kemal Atatürk. But considering specifically the marine realm, the concepts of "conservation" and "biodiversity" are relatively new concerns of Turkey that were put into the governments agenda quite lately. Right after the inclusion of legal texts on nature conservation within the Turkish constitution (1982, i.e. article 56 - *the State shall take the necessary precautions towards the protection and utilization of natural resources*), Turkey has signed a couple of important treaties in the following years, such as the Barcelona and Bern conventions. Research efforts made during the last few decades have revealed that several priority habitats (as defined in EU Habitats Directive; such as *Posidonia oceanica* meadows, coralligenous habitats, marine caves etc.) and high number of endangered species are concentrated along the Aegean Sea coasts. These precious habitats thus deserve a special concern in nature conservation activities, but efforts spent so far were focused mostly on the monitoring of critically endangered species, while the ecosystem approach has not yet to be implemented. Laws have been designed to protect threatened and endangered species, but previous experiences have shown that species are effectively preserved if special attentions are paid primarily to habitats (Bianchi and Morri, 2000). This approach once more shows us the extreme importance of marine protected areas, urgently to be handled and established by the government using the available datasets obtained during several biodiversity projects carried out so far. An estimated 3461 km^2 of marine area is presently under legal protection (4% of total area) within 31 marine and coastal protected areas in Turkey, which is well far from the expected figures. In this review, the endangered marine species distributing throughout the Turkish Aegean Sea coasts are examined. Not only the Red Lists of IUCN were taken into consideration, but also the relevant international treaties signed by Turkey were also analyzed.

2. Status of Endangered Species of the Aegean Sea

An examination of Red Lists (IUCN) and appendices of rest of the international treaties (Barcelona and Bern conventions) have revealed the presence of 146 endangered marine species inhabiting the Aegean Sea, comprising 18 plant, 37 invertebrate and 90 vertebrate species (for full account, see the Appendix). In a couple of cases, entire species of a particular taxonomical group are assessed to be endangered; for example all 10 marine mammal species inhabiting the Aegean Sea were listed by IUCN red lists, as is the case for marine reptiles and Petromyzonti (Table 1). However, majority of the taxa has not yet evaluated by the IUCN experts or covered by appendices of treaties, so the proportion of endangered species as a percentage of the relevant local diversity is quite low - for example, out of 1056 marine arthropod species occurring along the Turkish Aegean Sea coast (Bakır *et al*., 2014), only seven species appear within red lists or appendices of other conventions, which makes 0.7% of the local diversity.

The Bern Convention constitutes an instrument of major importance for the conservation and sustainable use of biological diversity at the regional level, whose main objective is to conserve wild flora and fauna and their natural habitats, especially those requiring the co-operation of several States. With reference to marine taxa occurring in the Aegean Sea, 78 species are currently covered by the Bern Convention. There are only 6 marine plants included in App.I (3 algae species and 3 flowering plant species), while majority of the strictly protected species are animal taxa (49 sp.) and exploitation of 23 more species are to be regulated.

The Barcelona Convention comprises 22 contracting parties that are determined to protect the marine and coastal environment of the Mediterranean, while focusing to achieve sustainable development by boosting regional and national plans. By the recent revisions made, the Barcelona convention now includes 104 protected species inhabiting the Aegean Sea. The appendix II (endangered plant and animal species) lists 79 species, while 25 species were mentioned in appendix III.

Table 1. Number of threatened species in taxonomic groups in the Aegean Sea and their proportions as a percentage of the relevant local diversity.

	Number of Threatened Species	% of Local Diversity
Plantae	18	3,6
Porifera	9	11
Bryozoa	1	0,7
Cnidaria	7	5,8
Arthropoda	7	0,7
Mollusca	10	1,2
Echinodermata	3	3,9
Petromyzonti	1	100
Elasmobranchii	39	67,2
Actinopteri	20	4,5
Reptilia	3	100
Aves	18	50
Mammalia	10	100

IUCN is the world's main authority for the conservation status of species, and the red lists of threatened species prepared are the most comprehensive inventory of the global conservation status of organisms, assessing the risk of extinction of species. The regional (Mediterranean and Europe) red lists include 49 (critically endangered: 13, endangered: 15, vulnerable: 21) and 45 (regionally extinct: 2, CR: 13; EN: 13; VU: 17) species, respectively.

2.1. Marine Algae and Seagrasses

Of almost 800 marine floral species of Turkey, slightly over 500 species were recorded from the Turkish Aegean Sea coast (Taşkın *et al*., 2001; 2008), 3.6% of them are under protection. Among these, the *Cystoseira* species are among the most important marine ecosystem-engineers, forming extended canopies, which are sensitive to any human disturbances, like the decrease in water quality, the coastal development and the outbreak of herbivores (Gianni *et al*., 2013). By the recent revision of Barcelona convention, all *Cystoseira* species (except for *C. compressa*) were listed as endangered, corresponding to 10 species reported from Aegean coasts of Turkey (Taşkın *et al*., 2008). Seagrass meadows rank among the most productive coastal habitats (Figure 1), playing key roles in several ecological processes (see contributions presented in Aktan and Aysel, 2013). The overall decline of marine phanerogams in the Mediterranean has been measured as approximately 10% over the last 100 years, which does not trigger any of the threatened categories (thus several species were interpreted as "least concern"), but Bern evaluates three of the species as strictly protected, while Barcelona lists four species as endangered.

2.2. Marine Invertebrates

Among 37 endangered invertebrate species reported from the eastern Aegean Sea, Mollusca had the highest number of species (10 sp.), followed by Porifera (9 sp.), Cnidaria (7 sp.) and Arthropoda (7 sp.). Rest of the taxa is represented by a few number of species.

Some of the Mediterranean sponge species are under pressure mainly of epidemic diseases, direct and indirect effects of global warming and overfishing of bath sponges (Pronzato, 1999; Pronzato and Manconi, 2008), but threat factors at the Aegean Sea are primarily associated with antropogenic impacts (i.e. discharge of pollutants, alteration of coastal ecosystems, etc.). Following the severe epidemic during 1986, which was resulted by the mass mortality of sponges in several Mediterranean countries, the sponge fishery was banned in Turkey (Fishery Bulletin no.3/1 of General Directorate of Fisheries and Aquaculture).

The endangered molluscs of the Aegean Sea are threatened mainly by hobbyist activities (for example illegal collection of cowry shells), human consumption (such as of *Lithophaga lithophaga*) and bycatch of various fishing gears (i.e. bottom trawlers' impact on *Pinna* beds, see Figure 2) (Katsanevakis *et al*., 2008). Collection of a few species is banned by Turkish national measures, which certainly require an update.

As for the threatened marine crustaceans, the major negative impact is of course the over- and illegal fishing activities, likely to be remained unsolved because of ineffective governmental measures. Authors of this chapter have witnessed several times the fishing of endangered lobster species illegally out of the permitted season. Due to their high commercial values, many crustaceans are objected to IUU (illegal, unreported and unregulated) fishing.

Several anthozoa species play vital role as bio-constructors, creating habitats that act as a shelter for many other organisms, thus harboring a great biodiversity. Long-lived sessile invertebrates (like corals) are clearly more prone to extinction due to their very slow growth and recovery. The fragility of the colonies makes them very vulnerable to environmental or human-induced impacts, and even centuries maybe required (for example for black corals) to recover from disturbance. Of the cnidarians evaluated by IUCN so far, only a single species occurring at Aegean Sea is critically endangered (*Isidella elongata*); this species has very recently been recorded from Turkey, off Gökçeada coasts, without any description and figure (Gönülal and Güreşen, 2014). Considering the Turkish national legislations, there are only two cnidarian species banned for fishing - the gold coral (*Savalia savaglia*) and the red coral (*Corallium rubrum*). The existence of the latter species in Turkey is a matter of dispute and all relevant records lack scientific basis (see Çınar *et al*., 2014).

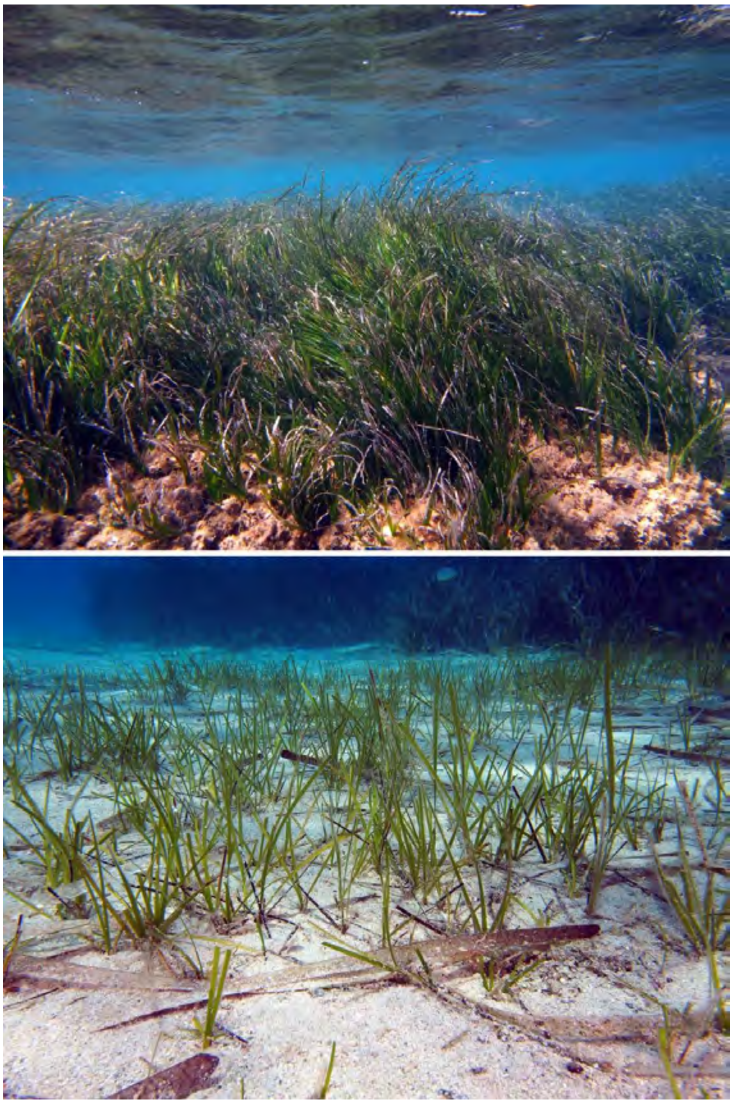

Figure 1. Widespread marine phanerogams of the Aegean Sea (up: *Posidonia oceanica*; bottom: *Cymodocea nodosa*) (Photos: M. Bilecenoğlu).

The Mediterranean red gorgonian *Paramuricea clavata*, which was classified as vulnerable by IUCN (in Mediterranean Red List), occurs along the northern Aegean Sea, forming dense colonies at 30-50 m depths on rocky bottom in Edremit (Deli Mehmet Sığlığı) and Saroz Bay. It is known to be a bio-constructor species hosting many other invertebrates and a key species in the coralligenous assemblages in the western Mediterranean (Scinto *et al.*, 2009). Like other gorgonians, this species is threatened by disturbances such as destructive fishing activities, anchoring, uncontrolled and over-frequent diving, mucilaginous algal aggregates, algal invasions and mass mortality caused by anomalous seawater temperature increases (Kipson *et al*., 2015).

Within the framework of a project performed in the Ayvalık National Park, a large mortality of *P. clavata* was observed at Deli Mehmet Sığlığı (30-35 m depth) in August 2012. Many dead and alive colonies of the species as well as those of *Eunicella cavolini* in the area were densely covered by mucilagous algal aggregates, that are known to bloom in some areas of the Mediterranean in summer (Rinaldi *et al*., 1995) (Figure 3). In the area where no mooring system is available, anchoring of diving boats was also observed to have a great impact on the colonies of this species as well as those of *Eunicella cavolini*, caused fatal damages or displacement of colonies. Arda *et al*. (2004) also reported that majority of colonies of *Eunicella singularis* (60% of colonies) in Saroz Bay (Toplarönü Burnu, İbrice) were badly damaged or death and that healthy colonies only comprised 20% of total colonies in the area.

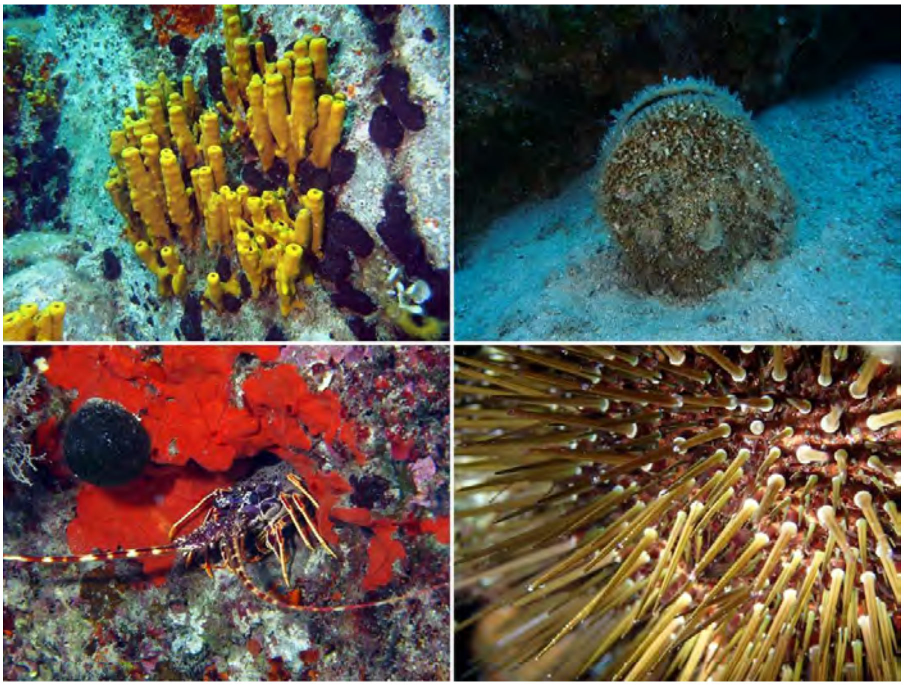

Figure 2. Examples of endangered invertebrate species from the Aegean Sea (upper left - *Aplysina aerophoba*; upper right - *Pinna nobilis*; lower left - *Palinurus elaphas*; lower right - *Paracentrotus lividus*) (photos: M & D. Kaya Bilecenoglu)

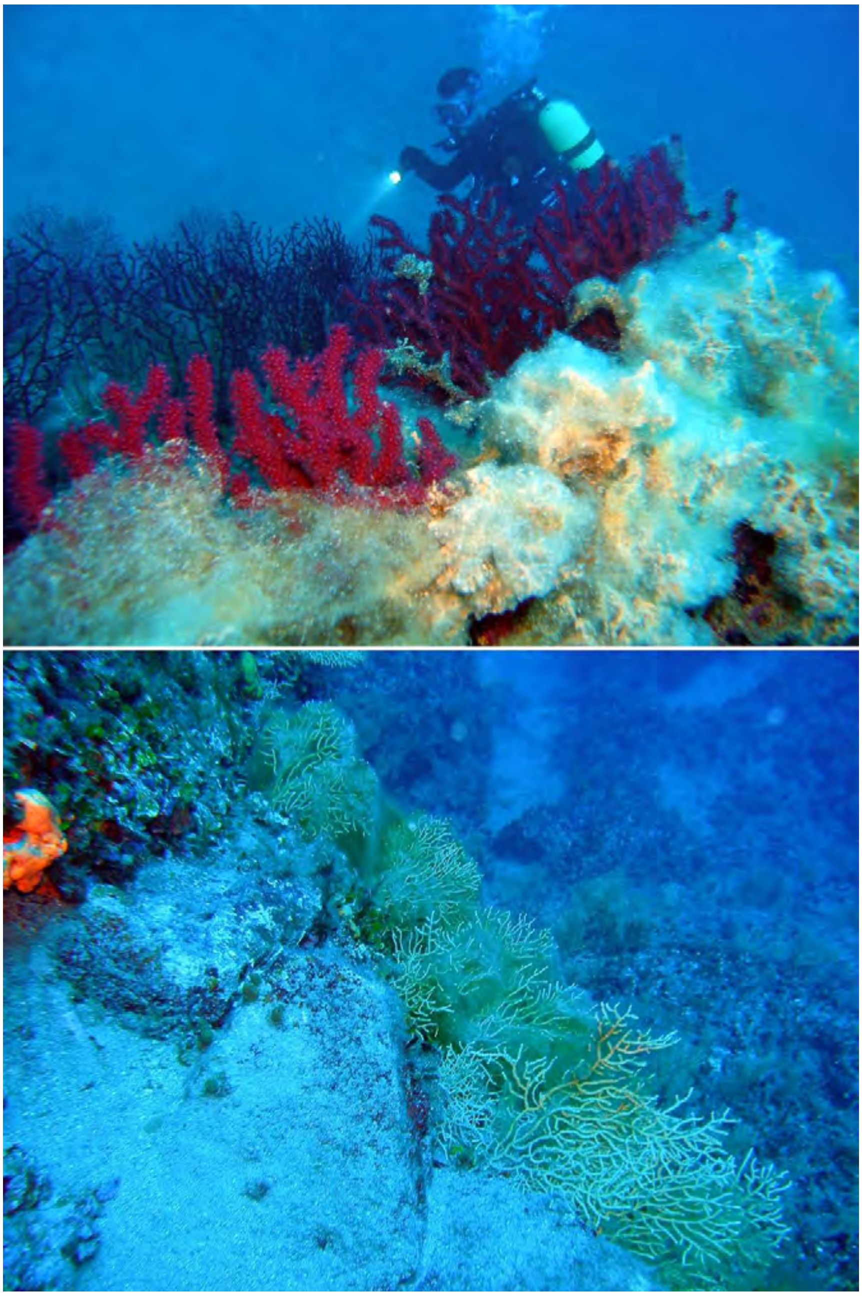

Figure 3. Mucilagous algal aggregates threatening *Paramuricea clavata* (upper picture) and *Eunicella cavolini* (lower picture) in Ayvalık National Park (Photos: M.E. Çınar).

2.3. Marine Vertebrates

Among all marine taxa of the Aegean Sea, none were represented by such a high number of endangered species, as vertebrates do. From a total of 90 threatened vertebrates, majority belonged to fishes (especially cartilaginous ones). Problems that several Mediterranean fish populations have been subjected to were mentioned in hundreds of scientific papers, in which solutions are already proposed: reinforce fishing regulations, create new marine reserves, reduce pollution and review fishing quotas, in particular the number of captures allowed for threatened species (Abdul-Malak *et al*., 2011). Turkey is yet to step forward in conservation of endangered fish, where we still witness tragic actions taken by the government - such as the absurd permission of spearfishing of the Mediterranean dusky grouper, by the recent official fishery bulletin.

Reptilia are represented by 3 sea turtle species in the Aegean Sea, which are almost exclusively dependent on their nesting sites along the northern Levantine shores (Türkozan and Kaska, 2010). Sea turtle sightings at the Aegean Sea is thus relatively low when compared to Levantine shores, and major threats they face with is deliberate killing, incidental fishery catch, boat strikes (especially during high tourism season, see Figure 4), habitat degradation and pollution. Marine mammals of the Aegean Sea include 9 cetaceans and 1 pinniped species, all listed under threat categories of red lists and covered by many national/international legislations, indicating their very high level of importance. Common threats of the cetacean species are reduced food availability caused by overfishing and environmental degradation, entanglement in fishing gear and the accumulation of toxins in their bodies from chemical pollution; while the current dramatically low population of the single pinniped (*Monachus monachus*) is in part due to the loss of appropriate habitat for breeding and feeding (foraging), marine pollution, diseases, disturbance from maritime traffic and poor enforcement of legal protection measures (IUCN, 2012).

3. Conclusive Remarks

Four MPAs are present along the Turkish Aegean Sea coastline: (1) Foça Special Environmental Protection Area (SEPA), (2) Datça-Bozburun SEPA, (3) Gökova SEPA, and (4) Saros Bay SEPA. All of these areas are very important ecosystems for seagrass meadows, coralligenous habitats, several seabirds, cetaceans, monk seals, marine turtles, endangered sponge and coral species. However, the above mentioned localities are alleged to be "under protection", since the status they bear do not prevent or decelerate direct and indirect human impact (for example coastal urbanization, fishing activities, pollution etc.). It is not principally more MPA's we need, but better managed and regulated protected areas.

With reference to lack of bio-ecological knowledge on several endangered marine species, a higher research effort is required, since taking protective measures will be impossible without the absence of sound scientific data. Improving knowledge of under-studied and under-protected species/habitats is strictly dependent on improved governmental financing mechanisms. Persistence of governmental support plays a key role in reaching the principal targets as defined by the convention of biological diversity (CBD).

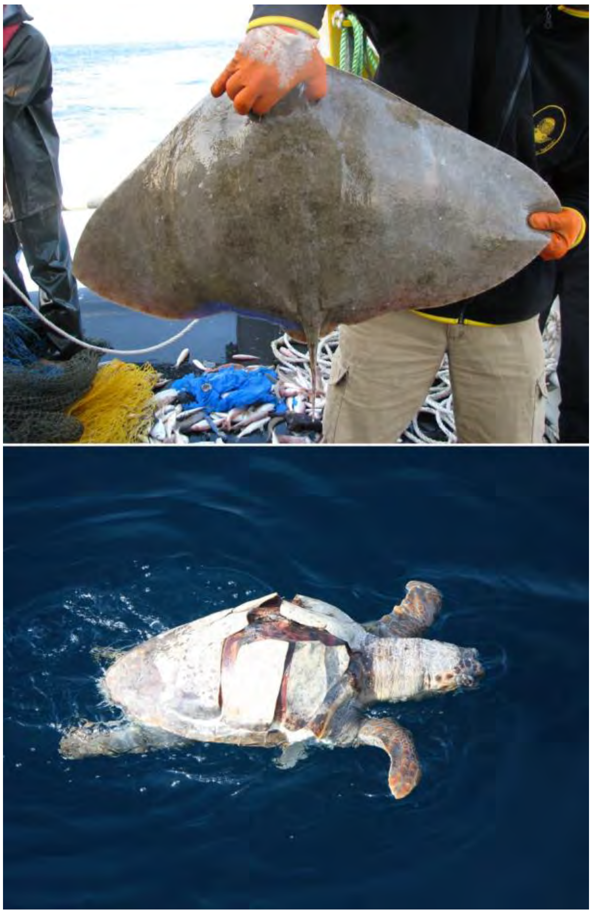

Figure 4. The spiny butterfly ray (*Gymnura altavela*) is a critically endangered species that is mostly threatened by incidental fishery catches (the individual in the photo was immediately released to the sea alive). The lower photo belongs to a *Caretta caretta* most likely died because of a boat strike. (Photos: B. Ergev and M. Bilecenoglu).

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Appendix. Endangered species of the eastern Aegean Sea (RL1: global red list; RL2: Europe red list; RL3: Mediterranean red list). Red List Categories: RE - regionally extinct, CR - critically endangered, EN - endangered, VU - vulnerable. Description of Bern Convention Appendices - App.I: strictly protected flora species; App.II: strictly protected fauna species; App.III: protected fauna species. Description of Barcelona Convention Appendices - App.II: List of endangered and threatened species; App.III: List of species whose exploitation is regulated.

Group/Species	RL1	RL2	RL3	Bern	Barcelona
ALGAE					
Caulerpa prolifera (Forsskål) J.V.Lamouroux	-	-	-	App.I	App.II
Cystoseira amentacea (C.Agardh) Bory	-	-	-	App.I	-
Cystoseira mediterranea Sauvageau	-	-	-	App.I	-
Cystoseira spp. (except *C.compressa*)	-	-	-	-	App.II
Sargassum acinarium (Linnaeus) Setchell	-	-	-	-	App.II
Sargassum hornschuchii C.Agardh	-	-	-	-	App.II
Lithophyllum tortuosum (Esper) Foslie	-	-	-	-	App.II
SPERMATOPHYTA				-	-
Posidonia oceanica (Linnaeus) Delile	-	-	-	App.I	App.II
Cymodocea nodosa (Ucria) Ascherson	-	-	-	App.I	App.II
Zostera marina Linnaeus	-	-	-	App.I	App.II
Zostera noltei Hornemann	-	-	-	-	App.II
PORIFERA				-	
Aplysina aerophoba (Nardo, 1833)	-	-	-	-	App.II
Aplysina cavernicola (Vacelet, 1959)	-	-	-	App.II	App.II
Axinella cannabina (Esper, 1794)	-	-	-	-	App.II
Axinella polypoides Schmidt, 1862	-	-	-	App.II	App.II
Geodia cydonium (Jameson, 1811)	-	-	-	-	App.II
Hippospongia communis (Lamarck, 1814)	-	-	-	App.III	App.III
Sarcotragus foetidus Schmidt, 1862	-	-	-	-	App.II
Spongia officinalis Linnaeus, 1759	-	-	-	App.III	App.III
Tethya aurantium (Pallas, 1766)	-	-	-	-	App.II
BRYOZOA					
Hornera lichenoides (Linnaeus, 1758)	-	-	-	-	App.II
CNIDARIA					
Cladocora caespitosa (Linnaeus, 1767)	EN	-	EN	-	App.II
Funiculina quadrangularis (Pallas, 1766)	-	-	VU	-	-
Isidella elongata (Esper, 1788)	-	-	CR	-	-
Lophelia pertusa (Linnaeus, 1758)	-	-	EN	-	App.II

Paramuricea clavata (Risso, 1826)	-	-	VU	-	-
Pennatula phosphorea Linnaeus, 1758	-	-	VU	-	-
Savalia savaglia (Bertoloni, 1819)	-	-	-	App.II	App.II
CRUSTACEA					
Homarus gammarus (Linnaeus, 1758)	-	-	-	App.III	App.III
Maja squinado (Herbst, 1788)	-	-	-	App.III	App.III
Ocypode cursor (Linnaeus, 1758)	-	-	-	App.II	App.II
Palinurus elephas (Fabricius, 1787)	VU	-	-	App.III	App.III
Scyllarides latus (Latreille, 1803)	-	-	-	App.III	App.III
Scyllarus arctus (Linnaeus, 1758)	-	-	-	App.III	App.III
Scyllarus pygmaeus (Bate, 1888)	-	-	-	App.III	App.III
MOLLUSCA					
Charonia variegata (Lamarck, 1816)	-	-	-	App.II	App.II
Dendropoma petraeum (Monterosato, 1884)	-	-	-	App.II	App.II
Erosaria spurca (Linnaeus, 1758)	-	-	-	App.II	App.II
Luria lurida (Linnaeus, 1758)	-	-	-	App.II	App.II
Ranella olearium (Linnaeus, 1758)	-	-	-	App.II	App.II
Tonna galea (Linnaeus, 1758)	-	-	-	App.II	App.II
Zonaria pyrum (Gmelin, 1791)	-	-	-	App.II	App.II
Lithophaga lithophaga (Linnaeus, 1758)	-	-	-	App.II	App.II
Pholas dactylus Linnaeus, 1758	-	-	-	App.II	App.II
Pinna nobilis Linnaeus, 1758	-	-	-	-	App.II
ECHINODERMATA					
Centrostephanus longispinus (Philippi, 1845)	-	-	-	App.II	App.II
Ophidiaster ophidianus (Lamarck, 1816)	-	-	-	App.II	App.II
Paracentrotus lividus (Lamarck, 1816)	-	-	-	App.III	App.III
PETROMYZONTI					
Petromyzon marinus Linnaeus, 1758	-	-	-	App.III	App.III
ELASMOBRANCHII					
Alopias superciliosus Lowe, 1841	-	EN	-	-	-
Alopias vulpinus (Bonnaterre, 1788)	VU	EN	VU	-	-
Carcharhinus plumbeus (Nardo, 1827)	VU	EN	EN	-	App.III
Carcharias taurus Rafinesque-Schmaltz, 1810	VU	CR	CR	-	App.II
Carcharodon carcharias (Linnaeus, 1758)	VU	CR	EN	App.II	App.II
Centrophorus granulosus (Bloch & Schneider, 1801)	VU	CR	VU	-	App.III
Cetorhinus maximus (Gunnerus, 1765)	VU	EN	VU	App.II	App.II
Dalatias licha (Bonnaterre, 1788)	-	EN	-	-	-
Dasyatis centroura (Mitchill, 1815)	-	VU	-	-	-

Dasyatis pastinaca (Linnaeus, 1758)	-	VU	-	-	-
Dipturus batis (Linnaeus, 1758)	CR	CR	CR	-	App.II
Echinorhinus brucus (Bonnaterre, 1788)	-	EN	-	-	-
Galeorhinus galeus (Linnaeus, 1758)	VU	VU	-	-	App.II
Glaucostegus cemiculus (Geoffroy Saint-Hilaire, 1817)	EN	EN	EN	-	App.II
Gymnura altavela (Linnaeus, 1758)	VU	CR	CR	-	App.II
Heptranchias perlo (Bonnaterre, 1788)	-	-	VU	-	App.III
Hexanchus griseus (Bonnaterre, 1788)	-	-	VU	-	-
Isurus oxyrinchus Rafinesque, 1810	VU	-	CR	App.III	App.II
Lamna nasus (Bonnaterre, 1788)	VU	CR	CR	App.III	App.II
Leucoraja circularis (Couch, 1838)	EN	EN	CR	-	App.II
Mobula mobular (Bonnaterre, 1788)	EN	EN	EN	App.II	App.II
Mustelus asterias Cloquet, 1819	-	-	EN	-	App.III
Mustelus mustelus (Linnaeus, 1758)	VU	VU	EN	-	App.III
Mustelus punctulatus Risso, 1827	-	VU	-	-	App.III
Myliobatis aquila (Linnaeus, 1758)	-	VU	-	-	-
Odontaspis ferox (Risso, 1810)	VU	CR	VU	-	App.II
Oxynotus centrina (Linnaeus, 1758)	VU	VU	CR	-	App.II
Pteromylaeus bovinus (Geoffroy Saint-Hilaire, 1817)	-	CR	-	-	-
Prionace glauca (Linnaeus, 1758)	-	-	VU	App.III	App.III
Raja radula (Delaroche, 1809)	EN	EN	-	-	-
Raja undulata Lacepède, 1802	EN	-	EN	-	-
Rhinobatos rhinobatos (Linnaeus, 1758)	EN	EN	EN	-	App.II
Rostroraja alba (Lacepède, 1803)	EN	CR	CR	App.III	App.II
Sphyrna zygaena (Linnaeus, 1758)	VU	-	VU	-	App.II
Squalus acanthias Linnaeus, 1758	VU	EN	EN	-	App.III
Squatina aculeata Cuvier, 1829	CR	CR	CR	-	App.II
Squatina oculata Bonaparte, 1840	CR	CR	CR	-	App.II
Squatina squatina (Linnaeus, 1758)	CR	CR	CR	App.III	App.II
ACTINOPTERI					
Acipenser stellatus Pallas, 1770	CR	RE	-	App.III	-
Acipenser sturio Linnaeus, 1758	CR	-	-	App.II	App.II
Alosa fallax (Lacepede, 1803)	-	-	-	App.III	App.III
Anguilla anguilla (Linnaeus, 1758)	CR	-	-	-	App.III
Dentex dentex (Linnaeus, 1758)	VU	VU	VU	-	-
Epinephelus marginatus (Lowe, 1834)	EN	EN	EN	App.III	App.III
Hippocampus hippocampus (Linnaeus, 1758)	-	-	-	App.II	App.II
Hippocampus guttulatus Cuvier, 1829	-	-	-	App.II	App.II

Huso huso (Linnaeus, 1758)	-	RE	-	App.III	App.II
Labrus viridis Linnaeus, 1758	VU	VU	VU	-	-
Merluccius merluccius (Linnaeus, 1758)	-	-	VU	-	-
Opeatogenys gracilis (Canestrini, 1864)	-	-	VU	-	-
Orcynopsis unicolor (Geoffroy Saint-Hilaire, 1817)	-	VU	-	-	-
Pomatoschistus minutus (Pallas, 1770)	-	-	VU	App.III	-
Sciaena umbra Linnaeus, 1758	-	-	VU	App.III	App.III
Scophthalmus maximus (Linnaeus, 1758)	-	VU	-	-	-
Syngnathus abaster Risso, 1827	-	-	-	App.III	-
Thunnus thynnus (Linnaeus, 1758)	EN	-	EN	-	App.III
Umbrina cirrosa (Linnaeus, 1758)	-	VU	VU	App.III	App.III
Xiphias gladius Linnaeus, 1758	-	-	-	-	App.III
REPTILIA					
Caretta caretta (Linnaeus, 1758)	EN	-	-	App.II	App.II
Chelonia mydas (Linnaeus, 1758)	EN	-	-	App.II	App.II
Dermochelys coriacea (Vandelli, 1761)	VU	-	-	App.II	App.II
AVES					
Gavia arctica (Linnaeus, 1758)	-	-	-	App.II	-
Gavia stellata (Pontoppidan, 1763)	-	-	-	App.II	-
Hydrobates pelagicus (Linnaeus, 1758)	-	-	-	App.II	App.II
Calonectris diomedea (Scopoli, 1769)	-	-	-	App.II	App.II
Puffinus yelkouan (Acerbi, 1827)	-	VU	-	App.II	App.II
Microcarbo pygmaeus (Pallas, 1773)	-	-	-	App.II	App.II
Phalacrocorax aristotelis (Linnaeus, 1761)	-	-	-	App.II	App.II
Pelecanus crispus Bruch, 1832	-	VU	-	App.II	App.II
Pelecanus onocrotalus Linnaeus, 1758	-	-	-	App.II	App.II
Chlidonias hybrida (Pallas, 1811)	-	-	-	App.II	-
Chlidonias leucopterus (Temminck, 1815)	-	-	-	App.II	-
Chlidonias niger (Linnaeus, 1758)	-	-	-	App.II	-
Gelochelidon nilotica (Gmelin, 1789)	-	-	-	App.II	App.II
Hydroprogne caspia (Pallas, 1770)	-	-	-	App.II	App.II
Larus armenicus Buturlin, 1934	-	-	-	-	App.II
Sternula albifrons (Pallas, 1764)	-	-	-	App.II	App.II
Sterna hirundo Linnaeus, 1758	-	-	-	App.II	-
Sterna paradisaea Pontoppidan, 1763	-	-	-	App.II	-
MAMMALIA					
Balaenoptera physalus (Linnaeus, 1758)	EN	-	VU	App.II	App.II
Delphinus delphis Linnaeus, 1758	-	-	EN	App.II	App.II

Grampus griseus (G. Cuvier, 1812)	-	-	-	App.II	App.II
Monachus monachus (Hermann, 1779)	CR	CR	CR	App.II	App.II
Physeter macrocephalus Linnaeus, 1758	VU	VU	EN	App.II	App.II
Phocoena phocoena (Linnaeus, 1758)	-	VU	-	App.II	App.II
Pseudorca crassidens (Owen, 1846)	-	-	-	App.II	App.II
Stenella coeruleoalba (Meyen, 1833)	-	-	VU	App.II	App.II
Tursiops truncatus (Montagu, 1821)	-	-	VU	App.II	App.II
Ziphius cavirostris Cuvier, 1823	-	-	-	App.II	App.II

CETACEAN IN THE AEGEAN SEA

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1. Introduction

Turkey and Greece have a long coastline along the Aegean Sea, extending more than 10,000 km in total. Twelve cetacean species are known to occur in this area (Beaubrun 1995, Öztürk 1996, Frantzis 2009, Notarbartolo di Sciara and Birkun 2010) (Table 1).

Table 1. Cetacean species list in the Aegean Sea

Species	English name	Visibility	IUCN status
Phocoena phocoena relicta	Black Sea Harbour porpoise	Regular	EN
Delphinus delphis	Short-beaked Common dolphin	Regular	EN*
Tursiops truncatus	Common Bottlenose dolphin	Regular	VU*
Stenella coeruleoalba	Striped dolphin	Regular	VU*
Grampus griseus	Risso's dolphin	Regular	DD*
Ziphius cavirostris	Cuvier's beaked whale	Regular	DD*
Physeter macrocephalus	Sperm whale	Regular	EN*
Globicephala melas	Long-finned pilot whale	Possible Visitor	DD*
Pseudorca crassidens	False killer whale	Visitor	DD
Balaenoptera physalus	Fin whale	Visitor	VU*
Balaenoptera acutorostrata	Minke whale	Visitor	LC
Megaptera novaeangliae	Humpback whale	Visitor	LC

EN: Endangered, VU: Vulnerable, LC: Least Concern, DD: Data Deficient (http://www.iucnredlist.org)
*Mediterranean subpopulation

In general, there have been limited studies on the cetaceans in the Aegean Sea and most knowledge has been collected by sporadic sightings and by studying stranded animals (Figure 1). For example, for *G. melas*, there have been some observations by fishermen, including one sighting in Saros Bay in 1993 (pers. comm. from the fishermen by B. Öztürk).

2. Distribution and Stock Structure, Abundance

Several surveys have been conducted on cetacean fauna in the Turkish Aegean coasts (Topaloglu *et al*. 1990, Dede and Öztürk 2007, Öztürk *et al*. 2009, Altuğ *et al*. 2011) (Table 2). According to these studies, *D. delphis, T. truncatus, S. coeruleoalba, G. griseus* were observed as common small cetaceans in the Aegean Sea. However, these surveys were not dedicated surveys for learning the abundance of cetaceans. Any information regarding the abundance and stock structure is absent. Bengil (2013), however, studied bottlenose dolphins in Izmir Bay by using both opportunistic platforms and photo ID, estimating the population size as 190 individuals in the outer part of the bay.

Table 2. Cetacean surveys carried out in Turkish Aegean Sea coasts

Period	Area	Total effort	Encounter rate	Reference
Summer 2006	Northern Aegean Sea	194nm	0.56 sighting/10 nm	Altuğ *et al*. 2011
Autumn 2006	Northern Aegean Sea	194nm	0.41 sighting/10 nm	Altuğ *et al*. 2011
Winter 2007	Northern Aegean Sea	194nm	0.31 sighting/10 nm	Altuğ *et al*. 2011
Spring 2007	Northern Aegean Sea	194nm	0.46 sighting/10 nm	Altuğ *et al*. 2011
April-May 2005	Aegean Sea, TSS	1800km	0.11 sightings/10 nm)	Dede and Öztürk 2007
Summer 2007	Aegean Sea	639nm	0.0062 sightings/nm	Öztürk *et al*. 2009
Summer 2008	Aegean Sea	653nm	0.034 sightings/nm	Öztürk *et al*. 2009

Besides these, acoustic/visual survey was made by IFAW/MCRI/PCRI in summer 2013 in the whole Aegean Sea and eastern Mediterranean. During this survey, in addition to the species mentioned above; there were *P. phocoena* sightings in the Northern Aegean Sea, especially in Saros Bay (Ryan *et al*. 2013). Another international survey was made in 2003-2007 in the southern Aegean and Mediterranean Sea by IFAW in which only *T. truncatus*, *S. coeruleoalba* and unidentified whale were recorded in the Aegean Sea, *D. delphis* and *P. macrocephalus* off the eastern coast of Rhodes in September 2007 (Boisseau *et al*. 2010).

Figure 1. Some photographs of cetaceans in the Aegean Sea
a: *S. coeruleoalba* (Tonay A., 2013), b: *D. delphis* (Tonay A., 2008), c: *S. coeruleoalba* mixed groups with *G. griseus* (Gönülal O., 2013, Gökçeada), d: *P. macrocephalus* (Ababay S., 2009, Alaçatı), e: *T. truncatus* (Dede A., 2007) f: *B. physalus* (Dede A., 1998, Kuşadası, Body length 14.5m)

Population structure has been studied in *P. phocoena* and *T. truncatus* in the Aegean Sea. All studies up to today have indicated that *P. phocoena* in the Aegean Sea, particularly in the northern part, belong to the Black Sea population of the Black Sea harbour porpoise *P. phocoena relicta* (Rosel *et al*. 2003, Frantzis *et al*. 2001, Fontaine *et al*. 2007, Viaud-Martinez *et al*. 2007). Most recent genetic study by Tonay *et al*. (2012, 2014) examined the mitochondrial DNA sequences of two individuals of *P. phocoena relicta* sampled in the northern and southern Aegean Sea coast of Turkey, resulting two different haplotypes which were found in the Black Sea in earlier studies. This supports the idea that harbour porpoises from the Black Sea dispersed into the Aegean through the Istanbul and Çanakkale Straits. For the Aegean Sea bottlenose dolphins, although sample size was low, genetic data support a recent bottleneck. Accurate abundance estimates are needed, as it is possible that local declines are occurring undetected (Gaspari *et al*. 2015). Besides, a preliminary genetic study made on the Risso's dolphin showed that a stranded individual in the Aegean Sea matches or very close to the genetic profile of Western Pacific individuals (Sönmez *et al*. 2012).

Between 1995 and 2012, six sporadic sightings of sperm whales (*P. macrocephalus*) were reported in the Turkish part of the Aegean Sea (Öztürk *et al*. 2013). Except one of the sightings in the northern part, the others were in the central part around the Ikaria Trough where the sperm whale clicks were also detected during the IFAW/CRI/PCRI survey in 2013 (Ryan *et al*. 2013). There were also several sightings between Rhodes and Fethiye, near the Fethiye Canyon which is one of the deepest parts of the Mediterranean Sea (Dede *et al.* 2012, Öztürk *et al*. 2013). Sperm whales feed only on cephalopods which are known to be abundant in deep waters of the Aegean and Mediterranean Sea.

There are several cetacean surveys made in the Greek side of the Aegean Sea especially between the Northern Sporades Islands and the Chalkidiki Peninsula, southern Aegean Sea (Frantzis *et al*. 2003, 2009). According to these surveys; sperm whales were distributed mainly in deep basins/trenches like Myrtoon, Cretan, northern Ikarion and northwestern Aegean Sea and Cuvier's beaked whales over steep depressions on the Aegean like the northern Sporades. Five sperm whales identified in the Aegean Sea opportunistically, one of them was resighted along the Hellenic Trench (south Crete) during the study made by Frantzis *et al*. (2014).

S. coeruleoalba regularly occurs and they often form mixed groups with *D. delphis* (pers. comm. A. Dede) and occasionally with *Grampus griseus* as well (Figure 1c), in the northern Aegean Sea, Saros Bay and Gökçeada as in the adjacent waters of the Aegean in the deep Gulf of Corinth (Frantzis and Herzing 2002) and open waters of Finike, southwestern coast of Turkey (Dede *et al.* 2012).

3. Direct takes

Turkey continued the cetacean fishery especially in the Black Sea until 1983. Presently, all cetaceans are under the legal protection in the Turkish waters. Historical records of dolphin fishery showed that a total of 84.9t of dolphins (including 22.5t in Izmir Province, 2.7t in Muğla Province) were caught in the Turkish Aegean Sea in 1969 according to Bilge (1972: cited in Tonay and Öztürk 2012) and 0.5t in 1970 (Berkes, 1977). The statistics were not collected systematically in those days, which makes these figures quite doubtful. Detailed information of species caught, areas, methods, etc, are not available. There has been no direct harvesting of dolphins since 1983 in Turkey. Culling of dolphins was encouraged by governments until the early 1970s and fishers interviewed in Greece confirmed that mass killings of dolphins were frequent in those times although the fishing area was not clearly indicated (Maynou *et al*. 2011). Intentional killing of dolphins competing with local gill and trammel net fisheries has been reported in the Greek coast of the Aegean Sea (Mitra *et al*. 2001).

Due to the increasing demand by the dolphinaria opened in the touristic areas on the Aegean and Mediterranean coasts of Turkey in current years, there have been some live-capture of *T. truncatus*. There were 23 animals caught during 2006-2007 and among them 6 were caught in the eastern Aegean Sea. They were all given permits by the Ministry of Agriculture and Rural Affairs (now Ministry of Food, Agriculture and Livestock). Some of them have died in captivity but the exact number is not known. However, two *T. truncatus* (named "Tom" and "Misha"), caught in Foça on the Aegean coast and kept under a poor condition, were later in 2012 released after the rehabilitation project supported by Born Free Foundation (U.K.) (http://www.bornfree.org.uk/campaigns/marine/hisaronu-dolphins/). They were tracked by satellite and radio tags for a few months and last observed near Seferihisar (Izmir) in July 2012 (pers.comm. A.M. Tonay). No live-capture has been given permission since 2007. The number of animals taken is small but capturing wild animals may effect the sustainability of local populations (or subpopulations), which should not be neglected, considering the social characteristics of these animals.

4. Strandings and Bycatch

Some species have been reported by stranding only and not by sighting of live animals in the Turkey. *Pseudorca crassidens* stranded live in Urla, Izmir in 1994 (Öztürk 1996) but no sighting has been reported in the Turkish water. *Ziphius cavirostris* had no live sighting but their strandings are known along the coast (Öztürk *et al.* 1998, Öztürk *et al*. 2011).

Between 1964-2012 totally 29 individuals (5 *T. truncatus*, 6 *S. coeruleoalba*, 5 *Z. cavirostris*, 4 *G. griseus*, 3 *P. phocoena*, 2 *D. delphis*, 1 *P. crassidens*, 1 *P. macrocephalus*, 1 *B. physalus,* 1 *Mesoplodon* sp.) were found stranded on the Turkish coasts of the Aegean and Mediterranean Sea (Marchessaux 1980, Öztürk and Öztürk 1998, Güçlüsoy 2007, Öztürk *et al*. 2011, Tonay *et al*. 2009, Tonay and Dede 2013) (Figure 2). In the Greek coats, there are several hundred stranding records (Frantzis *et al*. 2009). In addition to these species, *M. novaeangliae* and *B. acutorostrata* were recorded once each as sighting and stranding, respectively (Frantzis *et al*. 2009). In

2014, a male conjoined dicephalic bottlenose dolphin calf was found dead on the beach of Dikili/İzmir, the Aegean coast of Turkey. This was the first case of conjoined cetacean reported in Turkey and the second in the Mediterranean Sea (Aytemiz *et al*. 2014). During the morbillivirus epizootic in Greece during 1991-1992, over 100 individuals, mostly striped dolphins, died in the Aegean Sea (Cebrian 1995).

Cetaceans have been incidentally caught in the swordfish driftnet fishery in the Turkish Aegean waters especially in Fethiye Region (Öztürk *et al*. 2001, Akyol *et al*. 2005, Dede 2008) until this fishery was banned in 2006. Although the use of driftnet has been banned since 2006, there are illegal fishing still existing in the area. The extent of bycatch is assumed less but still some threats exist. In Greece, main harmful fishing by species are *Grampus griseus* – longlines; *P. phocoena, D. delphis, T. truncatus* – artisanal fishery; *S. coeruleoalba* – drift nets (Frantzis *et al*. 2009).

5. Habitat degradation

The Aegean coasts of Turkey are heavily exploited by tourism, which is one of the most important sources of income for the country. This results in habitat loss as such facilities are built right on the coast and there are intense touristic activities using marine vehicles all along the coast. Chemical pollution and eutrophication caused by waste water, noise pollution and collision by ships, and prey depletion due to overfishing result in habitat degradation for cetaceans in the region. However, few studies have been carried out to examine the extent of such degradation for cetaceans in the Aegean Sea. The level of PCBs and PCB methyl suphone metabolities were determined in the blubber of four striped dolphins from Aegean Sea (Troisi *et al*. 1998).

Due to prey depletion, some dolphins, mainly *T. truncatus*, have been reported to steal fish and damage nets of both artisanal fishery and aquaculture (Frantzis 2007). This has resulted in some incidents that fishermen harassed dolphins. Although no direct evidence has been recorded in the Turkish coast of the Aegean Sea, a female *D.delphis* stranded in Gökçeada in 2014 had seven shot holes which implies that she was shot at a close-range (Figure 3).

6. Ecology

To understand the feeding ecology of cetaceans in the Turkish Aegean Sea, their stomach contents have been studied. Öztürk *et al*. (2007) examined cephalopod remains from the stomachs of three bycaught *S. coeruleoalba* and two *G. griseus*. For *S. coeruleoalba*, *Abralia veranyi* was the most common prey (51.2% of all the beaks found in this species), followed by *Onychoteuthis banksii* and *Heteroteuthis dispar*. For *G. griseus*, *Histioteuthis reversa* was the most common species. In the stomachs of *S. coeruleoalba*, there were remains of some fish and shrimps, while only cephalopod remains were detected in those of the *G. griseus*. Dede *et al.* (2015) examined six bycaught *S. coeruleoalba* stomach contents and indicated that the cephalopod species which mostly resembled the above study and the small-sized mesopelagic and bathypelagic fish species, especially *Diaphus* spp. and *Ceratoscopelus maderensis* from Myctophidae, were the most important food source for the striped dolphins. Seven fish species were reported for the first time in the stomach contents of striped dolphins in the Mediterranean Sea. In contrast to the western Mediterranean Sea, the small-sized mesopelagic and bathypelagic fish species were the most important food source for them in the Eastern Mediterranean Sea (Dede *et al.* 2015).

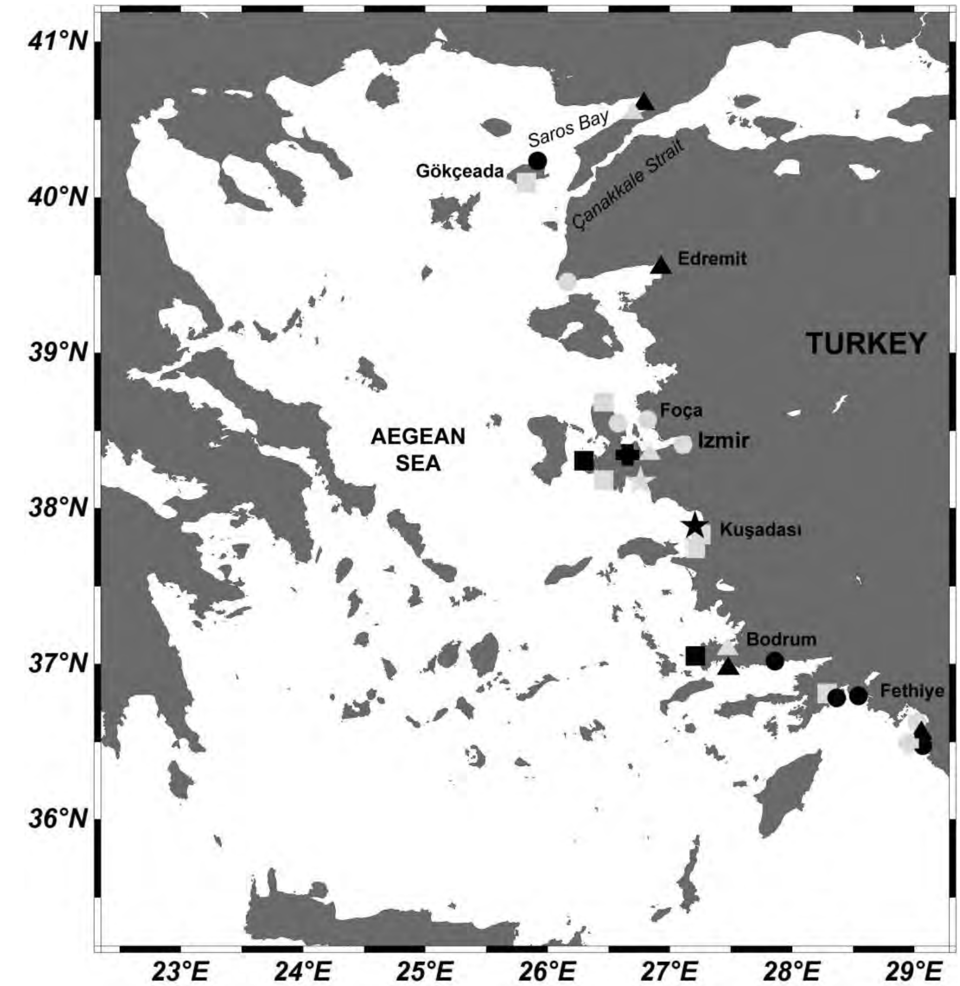

Figure 2. Stranding locations of cetaceans in the Turkish part of the Aegean Sea. (Black dots: *Z .cavirostris*, square: *D. delphis*, star: *B. physalus*, triangle: *G. griseus*, cross: *P. crassidens*) (Grey dots: *T. truncatus*, square: *S. coeruleoalba*, star: *P. macrocephalus*, triangle*: P. phocoena*, cross: *Mesoplodon* sp.)

Figure 3. Shotgun wounds on *D. delphis* and birdshots (Güreşen S O. 2014, Gökçeada)

The stomach content of 26 individuals of cetaceans (*T. truncatus, D. delphis, S. coeruleoalba, G. griseus* and *P. phocoena*) were studied in the northern Greek Aegean Sea (Milani *et al*. 2015). *D. delphis* fed mainly on species from the Clupeidae and Myctophidae and a few cephalopods; *T. truncatus* primarily on *Ophidion barbatum* (snake blenny), *Boops boops* (bogue), Clupeidae and cephalopods; *S. coeruleoalba* on small pelagic fish and especially on Myctophidae and few cephalopods; *P. phocoena* on Gobidae family followed by Clupeidae.

In some cases, parasites were also studied. Macroparasites, *Anisakis* spp., *Contraceucum* spp., *Pseudoterronova* spp. and *Steneurus minor* were identified in the stomachs of the striped dophins (Aytemiz *et al*. 2012). Besides, the ectoparasite, copepod *Pennella balaenoptera* had been reported for the first time in *P. phocoena* stranded on the southern Aegean coast of Turkey (Danyer *et al*. 2014).

7. Conservation

The most serious threats to cetaceans defined by Action Plan for the Conservation of Cetaceans in the Mediterranean Sea (UNEP/MAP RAC/SPA 1991) are: taking, defined as to harass, hunt, capture of kill or attempt to harass, hunt, capture of kill any cetaceans; pollution, as defined by the Convention for the Protection of the Mediterranean Sea against Pollution; reduction or depletion of food resources; incidental catches in fishing gear; degradation and disturbances of habitats caused by other factors such as seismic surveys, military exercises.

All cetaceans have been under legal protection in Turkey since 1983, which bans direct killing of cetaceans. This does not necessarily mean, however, there are conservation measures effectively and actively implemented for these animals. Threats mentioned above are largely unassessed and no prevention measures have been implemented. Turkey has not yet signed ACCOBAMS (Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area) (Greece has signed since 2001) but is a member state of the Barcelona Convention and GFCM (General Fisheries Commission for the Mediterranean) under FAO, by which

Turkey takes responsibility to monitor environmental status and fishery, respectively to implement the regional action plan for the conservation of cetacean species. There is no Turkish national action plan for cetacean conservation yet, although an initiative was taken to elaborate it in the early 1990's but this task was not completed due to the political shift in the authorities. The elaboration and implementation of a national action plan for cetacean conservation is urgently needed. The Conservation Plan for Short-beaked Common Dolphins in the Mediterranean Sea was prepared which indicated eight important common dolphin habitats in the Mediterranean including four sites in the Aegean Sea (Bearzi *et al.* 2004). In this plan, Turkey waters have been mentioned as important Mediterranean common dolphin habitat. Draft Conservation Plan for the Mediterranean Bottlenose Dolphin published after Eighth Meeting of the Scientific Committee of the ACCOBAMS (Monaco, 13-15 November 2012) with the Turkish participation and contribution placed as ANNEX 8; AREA 10 – Aegean Sea (Turkey) & Area 11. Turkish Strait System, Turkish Contribution to Conservation Action Plan of the Mediterranean Bottlenose Dolphin (Aegean Sea).

Four regions in the Aegean Sea and especially the deep-sea area of Rhodes in the south of the Aegean area are important habitats for cetaceans, particularly for the sperm whale and were recommended as a High Sea Marine Protected Area (Ozturk 2009). It is of high importance to establish conservation strategies for the feeding areas of the cetaceans. High sea marine protected areas also one of the options for more effective better protection of the cetacean species since some of them are highly migratory species.

9. Conclusion

There have been some progress in the data collection on cetaceans in the Turkish and Greek coast of the Aegean Sea. The number of both researchers and local people who are interested in cetaceans has been increasing. However, there should be government initiative or strategy to actively protect these species because they are facing a variety of threats in the area already.

Some species, such as *T. truncatus* and *D. delphis*, are already known as common in the area, while others, such as *G. melas* and *P. crassidens*, are known by few sightings or strandings, which may be the result of lack of effort. Increasing public awareness and organizing systematic surveys/research at the same time with the collaboration of the Greek and Turkish scientists will contribute to the understanding of cetacean fauna and their distribution in the Aegean Sea.

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MEDITERRANEAN MONK SEA (*Monachus monachus*, HERMANN 1779) IN THE AEGEAN SEA

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1. Introduction

Description: The Mediterranean monk seal is one of the largest species of the Phocidae family (Figure 1). Adult seals up to 310 cm in length and about 300 kg in weight. The newborns are 80-120 cm in length and about 20 kg in weight. An adult monk seal has very short, about 0.5-1 cm, and hard pelage, while that of the pups is soft and thick, about 1-1.5 cm long. The pelage colour shows wide range of variation. Usually the adult's back varies from dark brown, black to grey with dark spotting or brown with shades of grey. Colours may vary with age, older animals having paler silver-white coloring, with multi-shaped patches. Pups are generally born in a wooly blackish coat (Sergeant *et al*., 1978, Boulva 1979, Öztürk 1992a, Jefferson *et al*., 1993). Besides, in females the white patch is close to the tail with the umbilical slit within the patch, while in males the caudal margin almost reaches the umbilical slit and penile opening remains outside the ventral patch. (see details in González *et al*., 1996, Badosa *et al*., 1998 and Samaranch and González 2000).

Figure 1. Adult seal hauled out on the coast of Çeşme/İzmir (photo by O. Komut, 1999).

Life History: Monk seals are sexually mature when they reach 4th or 5th year of age (more than 2m in length). Existing studies and observations show that there is no specific season in which monk seals prefer to mate. Mating takes place in the sea. Gestation lasts about 10 to 11 months and births are known to happen mostly between May and November with a peak in September-October (King 1956). Births frequently take place in rocky coasts, sandy beaches, caves or grottoes. More recently, it seems that caves with underwater entrances are more preferred (Bareham and Fureddo 1975, Sergeant *et al*., 1978). Births usually occur every other year and a female gives only one pup each time. The duration of lactation period varies and has been reported to range from 6 weeks (Troitzky 1953) to more than 14 weeks (Mursaloğlu 1986, Aguilar et al. 2007). Their lifespan is estimated up to 40 years (Öztürk 1992a). Monk seals do not dive very deep, but they are generally capable to dive depths of 10-30 m and even deeper as 123 m recorded by using satellite tag (Dendrinos *et al*., 2007a) and usually surface every 4-5 minutes in order to breath. The average dive duration is indicated as between 1’49’’-4’56’’ (Öztürk *et al*., 1990), 4’29’’ (Öztürk and Dede 1998) and 4’42’’ (max 6’42’’) (Dendrinos *et al*., 2007a). Mediterranean monk seals mostly observed solitary, rarely pairs or groups. Small groups of five to twelve individuals from Mediterraean (Morocco, Greece, Turkey) or bigger groups up to 50-60 individuals only from the Atlantic coast-Cap Blanc were previously documented (Bareham and Fureddo 1975, Sergeant *et al*., 1978, Avella and Gonzalez 1984, Israëls 1992).

Diet: The Mediterranean monk seal is an opportunistic predator with their diet varying due to location, season and age of the seal as well as to the availability of food species (Gilmartin and Forcada 2002). The Mediterranean monk seal feeds in coastal areas on various fishes such as mullet, sea bream, bogues and mugil, cephalopods such as octopus and squid, and large crustaceans such as lobster and crabs. There have been some studies on Mediterranean monk seal diet from the Turkish and Greek waters such as Cebrian *et al*., (1990), Salman *et al*., (2001), Karamanlidis *et al*., (2011), Pierce *et al*., (2011), Karamanlidis *et al*., (2014).

Distribution and Abundance: The monk seal colonies used to be found throughout the Mediterranean, Marmara, Black Seas and the Atlantic coast of the northwestern African continent, including the Azores, Madeira and the Canary Islands (Monod 1948, Sergeant *et al*., 1978, Neves 1991). More recently, however, monk seals have disappeared from most of its original range. The species is also thought to be extinct or on the edge of extinction in the Marmara and Black Seas and the Adriatic coasts (Öztürk 1993, 1994c, Kıraç and Savaş 1996, Aguilar 1998). Today the world population is separated in reduced isolated subpopulations (Gonzalez, 2015). In the Atlantic, Madeira-Desertas Islands there are about 30 individuals (Pires *et al*., 2008). In Cape Blanc, the Western Sahara, 150-200 individuals survive in the single largest colony (Gonzalez *et al*., 2002, Martínez-Jaùregui *et al*., 2012). In the eastern Mediterranean, a subpopulation composed of 250–300 individuals in small scattered groups are distributed among the Turkish Aegean and Mediterranean coasts and islands, Greek coasts and islands (Güçlüsoy *et al*., 2004, Gücü *et al*., 2004, MOm 2015) (Figure 2.).

Some seals have been occasionally seen in the Marmara and Black Seas (Güçlüsoy *et al.*, 2004, Inanmaz *et al.*, 2014), on the Adriatic coast and the islands of Croatia (Gomerčić *et al.* 2011), in Italy (Mo 2011), and along the Mediterranean coast of Morocco and Algeria (Johnson *et al.*, 2006, Mo *et al.*, 2011), Albania (Anonymous 2012a), Egypt (Di Sciara and Fouad 2012), Israel (Scheinin *et al.*, 2011), Lebanon (Anonymous 2010a), Libya (Alfaghi *et al.*, 2013), Mallorca Spain (Anonymous 2008), and Syria (Abou-Zahra 2013). The world Mediterranean monk seal population estimates were made as 500-1000 individuals in the 1970's (Sergeant *et al,*. 1978); 400-500 individuals (Panou *et al.*, 1993), 200-300 individuals (Caltagirone 1995) and 415-615 individuals (Brasseur *et al.*, 1997) in the 1990's. The most recent world population estimate is fewer than 700 individuals (Karamanlidis *et al.*, 2015).

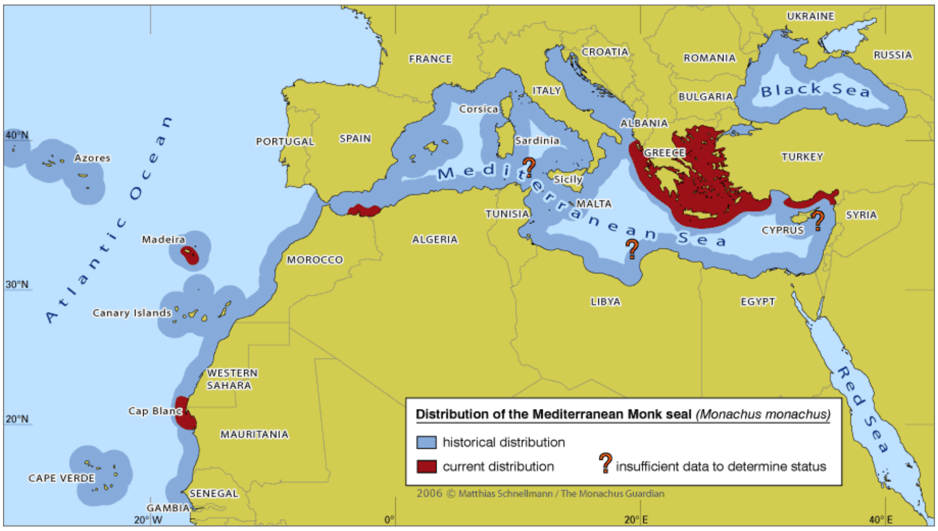

Figure 2. Historical range and current distribution of Mediterranean monk seal (Johnson *et al.*, 2006) (see also http://maps.iucnredlist.org/map.html?id=13653)

The first publication available regarding the monk seal in the Turkish coast was made by Captain Beaufort, who recorded in his diary that lots of monk seals were observed on the rocks near Taşucu in the southern part of Turkey (Beaufort, 1818). Later, Deveciyan (1914) and through 1950's (Kosswig, 1954) reported the existence of seals in the Turkish coasts. Mursaloğlu (1964) confirmed the occurrence of the Mediterranean monk seals via collecting and identifying four specimens from the Turkish waters. Boulva (1979) recorded 50-60 seals present in the Turkish waters. Between 1976-1978, Berkes *et al.*, (1978) estimated 165 (150-300) monk seals inhabiting Turkish coasts, in which 35 in the Mediterranean Sea, 90 in the Aegean Sea, 25 in the Marmara Sea and 15 in the Black Sea. Besides, there were estimates of 50-150 individuals by Sergeant *et al.*, (1978), 50-100 individuals by Marchessaux (1987), 20-50 by Öztürk *et al*., (1991) and 45 different individuals identified by Öztürk (1994a) and between 1986-1996, 44 by Öztürk (1998b). Later, an approximate estimation was given by Güçlüsoy *et al.,* (2004) as 104.

Recently, in the Turkish waters monk seal distribution focused in five main regions (Öztürk and Dede 1995, 2002, Kıraç *et al.,* 1997, Öztürk 1998a, Gücü 1998, Gücü *et al*., 2004, Güçlüsoy *et al*., 2004, Öztürk 2007). Besides, monk seal observations have been informed from northern Cyprus and the east coast of Turkey near the Syrian border (Gücü *et al*., 2009) (Figure 3).

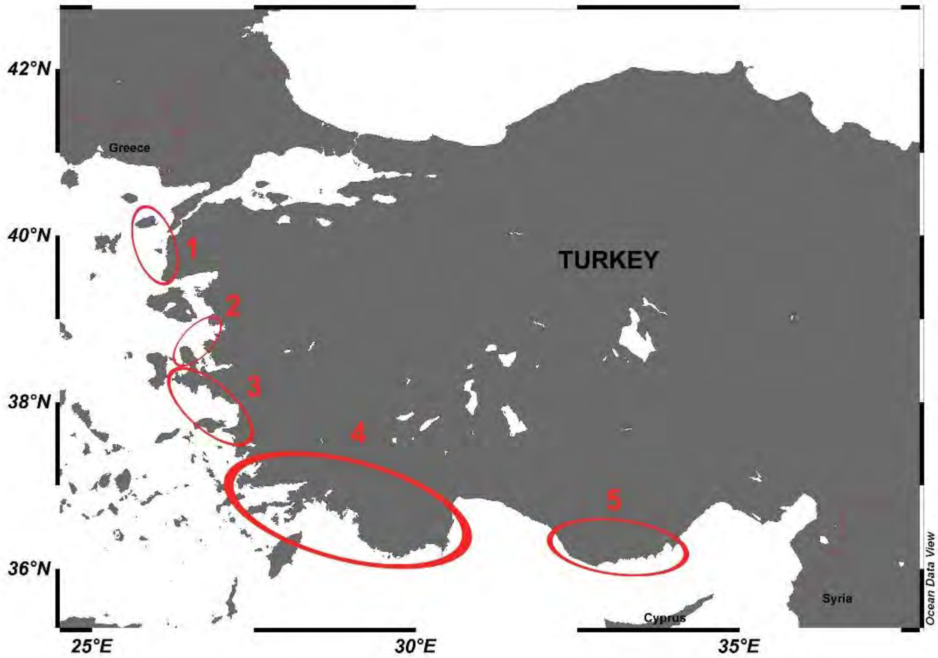

Figure 3. Five main regions of the distribution of the Mediterranean monk seals in Turkish Aegean and Mediterranean coasts. 1) Gökçeada and Baba Cape, 2) Foça and Karaburun, 3) Çeşme to Kuşadası-Dilek peninsula, 4) Bodrum and Antalya, 5) Cilician Basin; Gazipasa and Tasucu.

In this study, previously documented studies between Saros Bay (Northern Aegean Sea) to Finike (Soutwestern coasts of Turkey) were considered. The Aegean coasts of Turkey are roughly grouped as northern (above 39° latitude) central (between latitudes 37° and 39°) and southern parts (below 37° latitude).

2. Aegean Sea Population

The Aegean Sea is the most important monk seal habitat in the Turkish waters, including quiet and isolated islets and islands, calm inlets, beaches and underwater caves, although today these are under the pressure of anthropogenic disturbance. Sergeant et al. (1978), although it the 1970's, indicated that the Aegean Sea is the main center with a great number of population of the species. Güngör (1981) mentioned several areas as monk seal habitats, such as Kuşadası, Dilek Peninsula, Bodrum Peninsula, Datça Peninsula, around Fethiye, around Marmaris, Hisarönü Bay, around Çeşme and Alaçatı. Mursaloğlu (1991) mentioned 22 different regions where seals were sigthed in the Turkish coasts. Öztürk *et al*., (1991) indicated 16 caves convenient for breeding out of 70 caves investigated. Öztürk (1994a) identified 15 caves only in a short coastline between Çeşme and Sığacık. Kıraç *et al.,* (1997) indicated 11 areas including important seal habitats in the Turkish coasts of the Aegean Sea (Figure 4).

Ronald and Healey (1974) reported seals' presence in the Turkish Aegean Sea and Sergeant *et al*., (1978) estimated 75 seals for the period between 1971 and 1976, Berkes *et al.,* (1979) indicated as 50 to 90 between 1976 and 1978, and for the mid 80's Marchessaux (1987) indicated a tentative estimate as 47 for the Turkish coasts of the Aegean Sea. The Aegean coast population is split up into small groups that frequent different stretches of coast. According to Mursaloğlu (1991), the most stable group of seals is found between Alacati and Seferihisar (Sığacık). Öztürk (1994a) identified 28 individuals between 1987-1994 and Öztürk (1998a) identified 41 individuals between 1986-1996 while 13 were dead.

In the northern Aegean Sea, Marchessaux (1987) indicated 10 seals in the mouth of Dardanelles (Çanakkale Strait) to Baba Cape including Gökçeada and Bozcada Islands. Öztürk (1992a) identified three seals (two adults and one subadult) around Gökçeada and Bozcaada Islands, Baba Cape and Saros Bay. During 1986-1996, Öztürk (1998a) identified 3 seals in the northern Aegean Sea, 5 seals in the central Aegean Sea including Foça pilot area and 7 seals between Karaburun to Kuşadası, in the southern part 8 seals between Kuşadası to Bodrum and 5 seals between Bodrum to Finike. Kıraç *et al*., (1998) indicated 22 seals for the 1992-1997 survey period in the Turkish Aegean coasts. Dede (1998) identified two individuals in Gökçeada Island. There is no information about the migration of these individuals to the Marmara Sea through the Çanakkale Strait (Dardanelles) or vice versa.

In the central Aegean Sea, Ayvalık to Foça and nearby islands, three-five seals etimated by Marchessaux (1987). Including Foça Pilot Project Area, five seals were determined by Öztürk (1994a,b) as three of them were old, one was adult and the other one was subadult. Öztürk and Dede (1995) mentioned potential seal habitats; seven caves and seven shelters in Foça and estimated three seal individuals by interviews with fishermen. Between 1991-1998, Güçlüsoy and Savaş (2003, 2004) mentioned that there were 11 caves that were potential seal habitats in Foça and they have observed nine seals, two of which were born inside the Foça Pilot Area. Kıraç and Güçlüsoy (2008) indicated at least three monk seals still exist in Foça Pilot Area according to the data obtained 2005–2008.

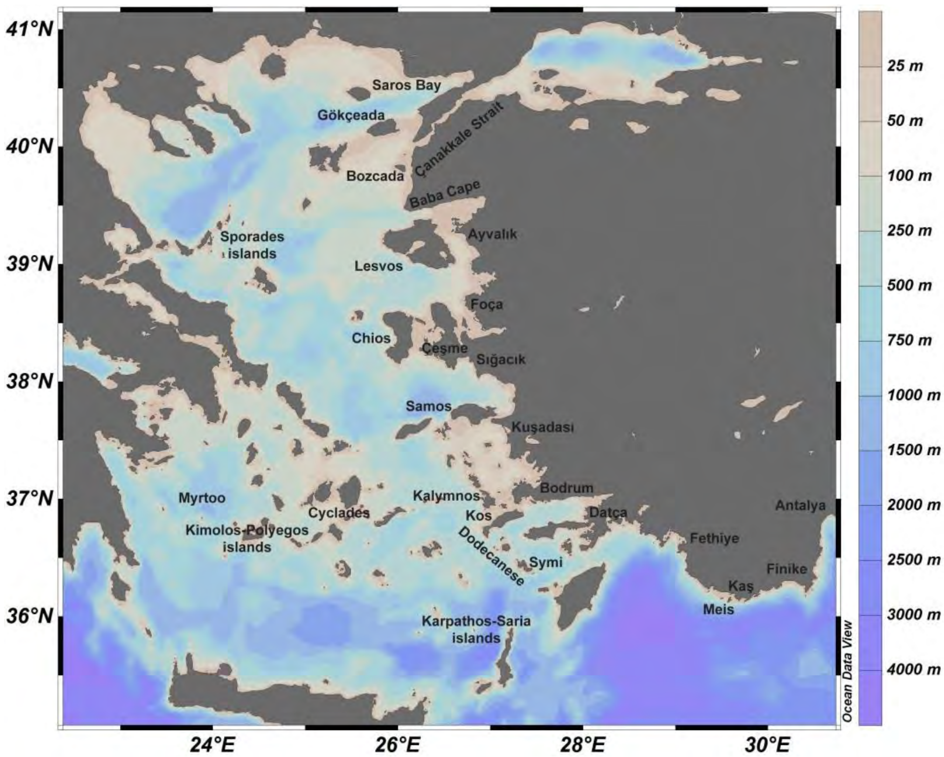

Figure 4. Main locations of monk seal populations in the Turkish coasts of the Aegean Sea

In the rest of the central Aegean Sea, Öztürk (1994a) reported three seals in Karaburun Peninsula. Kıraç and Veryeri (2009) reported totally 16 seals around Karaburun Peninsula between 1999-2009 and indicated currently five seals surviving there according to the last two years observation. Between Çeşme to Seferihisar Marchessaux (1987) estimated 10 animals, while Öztürk (1994a) identified seven individuals; four adults, one subadult and two juveniles. Marchessaux (1987) indicated two seals in Dilek National Park, then Öztürk (1994a,b) identified eight individuals between Kuşadası and the Bodrum Peninsula. These were four adults, two subadults and two juveniles.

In the southern part of the Aegean Sea, in Güllük Bay, north of the Bodrum Peninsula, Berkes (1976) mentioned eight seals while Berkes et al. (1979) at least four seals. Güngör (1981) indicated the seal occurrence around the Bodrum Peninsula as one in Yalıkavak, two in Toprak Island and two or three in Ören. Marchessaux (1987) reported five monk seals in the Bodrum Peninsula. Öztürk (1992a) mentioned six individuals in the Bodrum Peninsula and around the nearby islands and islets of Çavuş, Kiremit, Çatalada, Çavuş Adası, Yassıada, Karaada, and Kardak (İkizce). Öztürk (1992b) defined minimum three, maximum six individuals in the Kiremit Islands. Between Bodrum to Kadırga Cape five individuals were identified by Öztürk (1994a) as three of them were old, one was a young adult and the other one pup. Marchessaux (1987) indicated 10 seals around southwest of Marmaris and five seals from Fethiye to Kaş.

Since the mid 1990's the number of studies on monk seal distribution has increased. According to Kıraç and Veryeri (1996) 76 reliable seal sigthing data were obatained in the Bodrum Peninsula. Seals are mostly observed on the western and northwestern coasts of the peninsula covering the Küdür Peninsula, Kiremit and Çavuş Islands. Öztürk (1998c) recorded two pups and six adult monk seals in the above mentioned islands and islets.

During 1994-1998, 338 sightings were recorded in the Turkish part and approximately 63 individuals (35 northern Aegean, 28 southern Aegean) were estimated by Güçlüsoy *et al*., (2004). There is no accurate information on the actual number of seal population in Turkish coasts. "Re-estimating and Determining the Mediterranean Monk Seal Population in the Turkish Coasts of the Aegean and Mediterranean Sea" is placed as one of the actions on the National Action Plan for the Conservation of Mediterranean Monk Seal in Turkey.

3. Overlapping Areas and Greek Waters

Studies between the 70's to 90's reported the population estimates as 200-600 (Vamvakas *et al*., 1978), 400 (Ronald and Yeroulanos 1984), 80 (Cebrian and Vlachoutsikou 1992) 135-156 (Scoullos *et al*., 1994) for the Greek waters. Sergeant *et al*., (1978) stated that Dodecanese islands (Oniki Adalar) of Greece and adjacent coasts of Turkey is the main centre of the seals and estimated 150 seals around the Aegean Greek islands including Crete. In the opposite coast, Berkes (1982) estimated 50-100 seals in the southwest coast of Turkey. Ronald and Healey (1974) reported 150 seals estimated for the Greek Archipelagos in the Aegean Sea. Cebrian and Vlachoutsikou (1992) indicated 20 seals while Dendrinos (1998) 43 adult and 8 juvenile in Northern Sporades and Vlachoutsikou and Lazaridis (1990) reported minimum of 14 seals in Cyclades. Seal population in the Greek waters of the Aegean Sea reviewed and documented as 35 in the Northern Sporades, 43 in the Cyclades, 10-15 in the Myrtoo, 34-39 in the Eastern Aegean and 4-5 in the Samothraki Islands (Scoullos *et al*., 1994).

In the Greek waters of the Aegean Sea, recently three areas come to the forefront; the northern Sporades islands complex, the Cyclades; Kimolos-Polyegos-Gyaros islands and the Dodecanese islands and Northern Karpathos-Saria (MOm 2009, 2015).

Total estimated population size is indicated approximately 200 individuals in the Greek (Voultsiadou *et al*., 2012) and 63 (Güçlüsoy *et al.,* 2004) in the Turkish coasts. The seal population estimation was given as follows: more than 50 individuals in the Northern Sporades Islands, 50 in Kimolos-Polyaigos island complex in the southwestern Cyclades islands, approximately 60 in Gyaros, in the northern Cyclades Islands, and approximately 25 in Northern Karpathos and Saria (MOm 2015).

Between the Northern Aegean Sea and Kaş, there are many overlapping zones, where the seals travel freely between Turkey and Greece. In these areas, both countries can count and monitor same animals. Because there are several islands and islets borders are very close in the Aegean Sea. Berkes (1978), Ronald and Berkes (1979) and Öztürk (2007) indicated the possible migration of the monk seals in the Aegean Sea between Turkey and Greece and listed four priority areas; northern Aegean Sea, Samos to Kuşadası, Kastellerizon and Kaş, and Symi Island and Datça Peninsula. Marchessaux (1987) also pointed out that it would be arbitrary to make a specific distinction between the Greek and Turkish populations of monk seals in the Eastern Aegean since a number of Greek islands (Lesvos, Samos, Chios, Kos and Kastellerizon) are located only a few miles from the Turkish coasts and likely that some of the metapopulations are established over a home range extending both to Greek islands and stretches of the Turkish coastline.

In addition to those indicated, five overlap zones including Gökçeada, Samothraki and Limnos in the northern Aegean (Dede 1998) summarized by Öztürk and Dede (2002) and Öztürk (2007). Suggestions to overlap zones focused on the necessity of the international collaborative studies between Turkey and Greece and should be declared as international monk seal sanctuaries in the Aegean Sea.

5. Mortality

After the 1997 mass die-off in the monk seal colony of northwest coast of Africa-Cabo Blanco Peninsula, the importance of Aegean and eastern Mediterranean monk seal population has increased. The Cabo Blanco monk seal population between 1993-1996 was estimated as 317 seals, but a mass mortality event in 1997 reduced the population size to 109 (Forcada *et al*., 1999).

Twenty-four cases of seal deaths were recorded in the last 10 years (1986-1996) in all Turkish waters, of which 15 were reported from the Aegean and 9 from the Mediterranean Sea. Twelve of them (42 % of all deaths) were deliberately killed, six (27 %) were drowned in the nets-two of them entangled longline hooks, and the reason for other six deaths was not known (Oztürk 1998d). Öztürk (1998a) reported 13 deaths for Turkish Aegean coasts between 1986-1996, of which 5 were deliberate kiling, 5 entanglement, 3 unknown reason and among them 3 were pup. From these figures, we can assume hostile attitude of fishermen against the monk seals in Turkey.

Unfortunately, deliberately killing is the most frequent cause of death for Mediterranean monk seals; during 1985-1995, 32% in 79 (11 not from Aegean) cases in Greek waters (Androukaki *et al*., 1999), 1994-2002 one in 12 cases (Güçlüsoy *et al*., 2004), 12 in 24 cases (15 from Aegean) in Turkish waters (Öztürk 2007).

6. Threats

The potential threats to the Mediterranean monk seal were clearly identified since the First International Conference on the Mediterranean monk seal in 1978 (Ronald and Duguy 1979) and have not changed very much since then. They can be summarized as follows;

- Increased adult and juvenile mortality because of deliberate killing mostly by fisherman.
- Increased adult and juvenile mortality caused by incidental entanglement in fishing gear.
- Increased pup mortality caused by pupping in unsuitable locations, due to loss of suitable habitat.
- Poor condition due to lack of food as a result of overfishing.
- Reduced fecundity and pup survival caused by inbreeding depression.

Meanwhile, the main causes of the decline of the population i.e deliberate killings, entanglement to fishing gear, loss of habitat because of tourism (daily tours to seal habitats, recreational or cave diving etc. construction of hotels and other infrastructure, overurbanisation and marine pollution, and lack of food as a result of overfishing and illegal fishing, pollution, diseases have long been identified by researchers along the Mediterranean (Sergeant *et al*., 1978, Reijnders *et al*., 1988, Israëls 1992, Panou *et al*., 1993, IRSNB-SMRU 1994, Aguilar 1998, Johnson and Lavigne 1998, Bildt 2001, Öztürk and Dede 2002, Toplu *et al*., 2007, Karamanlidis *et al*., 2015). As a result of these threaths monk seals are disappearing in several areas.

Interaction with Fisheries; Commercial hunting of the species for their skin, blubber and meat has long since been banned, but deliberate killings until recently were continuing (Fig. 5.). The main reason was the rapid decline in the fish stocks resulting in an antagonism between fishermen and seals who share the same food source. Seals, in search of sufficient fish, are often attracted to fish in the nets and damage fishing nets during their attempt to take them (Fig. 6). Fishermen perceive the seals as buggers/pests and deliberately kill them to protect their livelihood. According to a study about the interaction between the monk seals and the artisanal fisheries, a considerable amount of damage is caused by monk seals per case (maximum 462.5 USD per case) but in terms of total economic impact it is found to be moderate (Güçlüsoy 2008). Incidentally, entanglements to fishing nets or longline is the cause of many monk seal mortalities in the Aegean. Accidental entanglement occurs mainly with fishing nets, and affects mostly pups and sub-adult seals (Güçlüsoy 2000, Veryeri *et al*., 2001, Karamanlidis *et al*., 2008).

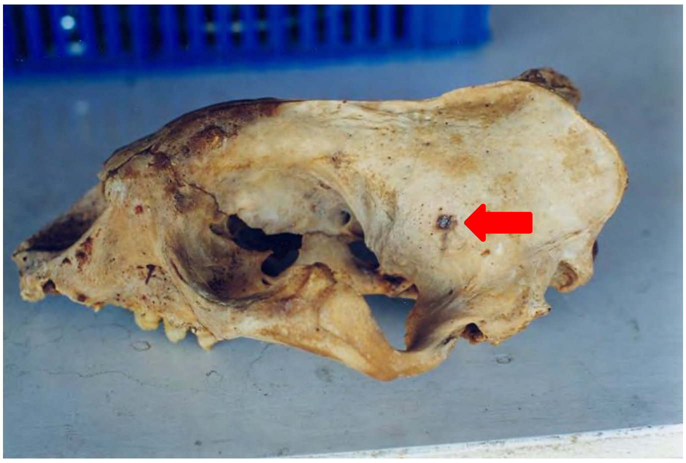

Figure 5. Deliberately killed seal, several bullets found in the body and some of them in the skull (photo by B. Öztürk, Gökçeada 1998).

Habitat degradation; The Mediterranean coasts of Turkey are heavily exploited by tourism, which is one of the most important sources of income for the country. This results in habitat loss as such facilities are built right on the coast and there are intense touristic activities using marine vehicles all along the coast. Chemical pollution and eutrophication-algal blooms caused by waste water and prey depletion due to overfishing also cause habitat degradation for monk seals in the Aegean Sea. However, few studies have been carried out to examine the extent of such degradation for monk seals in the Aegean Sea. Öztürk *et al*., (1990) investigated 12 caves as known seal habitats but they suggested all caves were abandoned by seals because of urbanisation and seals migrated from shore to isolated islands.

Figure 6. Three-hole net damage is commonly assumed as the damage made by seals, also described by Greek fishermen in Ronald and Healey (1974) (photo by A. Dede, Foça, 1994)

Increased juvenile mortality caused by pupping in unsuitable locations, due to loss of preferred habitat: Aborted pups or foetuses reported by Bareham and Fureddu (1975) with the evidence of the sensitive mother seals abandoning caves under human disturbance. Near big coastal settlements, habitat loss is the main threat for the decline in the numbers of monk seals. Due to the fast development and intensive urbanisation, suitable habitats for the monk seals are being destroyed or remain under the pressure of anthropogenic stress. There are many cases which formerly seal caves have been abandoned due to fast coastal development (Öztürk 1992a, 1998d, Yediler and Gücü 1996). Besides, during stormy periods, higher mortality rate of pups is caused by the dissapearance of haul-out sites at the end of the caves by waves and tides or by being washed away while their mothers leave them for feeding during lactation (Gazo *et al*., 2000).

Genetics: Previous studies indicated that declining seal numbers and isolation of colonies resulting in a decrease in gene flow which caused degredation of genetic diversity (Ronald and Yeroulanos 1984). The seals inhabiting the Aegean Sea cross between the Greek and Turkish waters. This situation is a positive factor for interpopulation genetic development and an important chance for the population continuity. But according to genetic analyses on mitochondrial and nuclear DNA by Pastor *et al*., (2007) and Karamanlidis *et al*., (2016) genetic variation was found to be extremely low in the Aegean Sea subpopulations. Low levels of genetic diversity suggested an important threat to survival and conservation of the species. For this reason, research and conservation in the known groups and overlapping areas such as Gökçeada-Samothraki-Limnos, Lesvos-Chios-opposite Turkish coasts, Dodecanese-Bodrum Peninsula vicinity, Datça Peninsula-Meis Island are of certain importance.

7. Status and conservation

The Mediterranean monk seal is a mammal facing the danger of extinction and listed as ''Endangered C2a(i) ver 3.1'' by the International Union for the Conservation of Nature and Natural Resources (http://www.iucnredlist.org/details/13653/0, Karamanlidis and Dendrinos 2015). Those status was ''critically endangered'' until year 2013 then change to ''endangered'' due to population trend assumed as increasing.

Increased interest for the conservation of the Mediterranean monk seal by many international bodies such as IUCN, WWF, UNEP, RAC/SPA, GFCM, governments, local environmental NGO's and scientists have already resulted in the elaboration to research and conservation programmes in the last decades. New strategies are currently in progress with the preparation of an Action Plan for the Conservation of the Mediterranean Monk Seal by international joint efforts (UNEP/MAP 2009, UNEP-RAC/SPA 2014). The Action Plans for the conservation of the species mainly focused on *in situ* conservation measures as habitat protection especially critical habitat, reduce interactions between seals and fisheries, scientific research on seal populations, education and public awareness campaigns and rescue/rehabilitation of orphaned or wounded seals etc.

Monk seals also listed on Appendix I of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES). It is also covered by the UNEP Bonn Convention on Migratory Species and the Bern Convention on the Conservation of European Wildlife and Natural Habitats. An Action Plan for the Management of the Mediterranean Monk Seal was adopted in 1987, launched under the Barcelona Convention. Turkey is the one of the member of several international conventions relevant to the protection of the Mediterranean monk seal as follows;

- Convention for the protection of the Mediterranean Sea against Pollution (Barcelona Convention), 1976 (signed by Turkey 1981)
- Protocol concerning Mediterranean Specially Protected Areas (SPA) of the Barcelona Convention (Geneva, 1982) (signed by Turkey 1988)
- Mediterranean Action Plan (MAP; 1989) (signed by Turkey 1989)
- Convention on the Conservation of Migratory Species of Wild Animals, signed in Bonn Convention, June 23rd 1979.
- Convention on the conservation of European wildlife and natural habitats, signed in Bern on September 19th 1979. (signed by Turkey 1984)
- Convention on International Trade in Endangered Species of wild fauna and flora, signed in Washington, March 3rd 1973 (CITES). (signed by Turkey 1996)
- Convention on Biological Diversity, 1992 (signed by Turkey 1997)

- EEC Directive on the conservation of natural habitats and wild flora and fauna (Directive 9243 of May 21st 1992).

National Legislation

Turkish national legislation consists of Environment Law No: 2872, Law on National Parks, Forest Law, Law on the Protection of Cultural and Natural Assets, Hunting law, Law of Fisheries, Establishment of Authority for the Protection of Special Protection Areas.

The conservation of the Mediterranean monk seal is subject to governmental regulations since 1977 by Fisheries Law no 1381 which provide complete protection of the Mediterranean monk seals in Turkish coasts.

For the conservation of the Mediterranean monk seal, Turkish National Strategy was prepared in 1991, and consequently a national seal committee was established for co-ordination of the monk seal conservation activities. The committee consists of representatives of related ministries, universities (İ.Ü., ODTÜ) and the NGO's (TUDAV, SAD, DHKD, TTKD). The ministry of environment acts as the co-ordination unit of the committee. As a pilot area, Foça, a small town on the Aegean coast was selected for the implementation of the national strategy. Foça Pilot project set a successful example that was followed by a similar conservation project in other small areas in Bodrum-Yalıkavak and Küdür Peninsula (Bodrum/Aegean Sea) in 1994, which were declared as 1st Degree Natural Assets (protected area for the conservation of seals), ensuring protection against landscape modification and constructions. While the national monk seal committee carries out irregular meetings whenever possible, a supplementary technical sub-committee including NGO's and universities working on the Mediterranean monk seals was established in 1997. The sub-committee determined the important monk seal sites in Turkey, mapped protected areas on the coast and prepared a list of current problems threatening the survival of this species. Fourteen sites in Turkey were classified as important habitats for the Mediterranean monk seals. The National Monk Seal Committee's consensus of opinion is to focus only on five "Monk Seal Protection Areas" (MSPAs) (Fig. 3) and to be urgently protected at the 14th National Monk Seal Committee meeting held in Ankara on 27 December 1999. However, no further attempt has been realized since then (see the link to related map and text http://www.tudav.org/index.php/tr/akdeniz/135-akdeniz-foku-arast-rmalar).

Public awareness

Enhancement of public awareness and education is very important component of the monk seals conservation management. Several campaigns have been made and educational materials have been disseminated by NGO's and universities (Fig. 7.).

During these activities, tourism professionals, local people, government agencies, personnel of national park, students, fishermen, port authorities, municipalities and newspapers have been targeted.

Figure 7. Example of TUDAV public awareness activities; coloring book for children and Booklet.

An orphan pup named 'Badem' found in Didim on 5 December 2006 was taken into rehabilitation by SAD-AFAG. After the rehabilitation, she was released back in Gökova Bay on 28 April 2007. She was, however, brought into temporary captivity during summer, both for her own safety and that of tourists with whom she was increasingly interacting. There is no information since she had a stillborn baby in 2011 (Anonymous 2010b; Anonymous 2012b). Consequently, Badem has made great contribution to increasing public awareness for monk seals in Turkey.

8. Conclusion

There have been some progress in the data collection on cetaceans in the Turkish and Greek coast of the Aegean Sea. The number of both researchers and local people who are interested in seals has been increasing. However, there should be government initiative or strategy to actively protect these species because they are facing variety of threats in the area already.

Every single Mediterranean monk seal individual is very important for such an endangered population. Conservation measures should be enforced at local and national levels more intensively for this species and also all their habitats. The survival chance of the monk seal in the Turkish Aegean Sea and Mediterranean Sea depends on the effective conservation measures. They are to stop deliberate killing, establishment and management of effective protected areas, restrictions on recreational and fishery activity especially around active caves, urgent studies about overlap zones, education to fishermen against the damage to the fishing gear and development of public awareness programs. To protect the Mediterranean monk seal, the most urgent problem in the Turkish coasts is to stop the deliberate killing of the monk seal. This may be realized with education and mass public awareness campaigns for the protection of the monk seal, starting from the fishermen.

Priorities for conservation actions include the enlargement of special protected areas and the establishment of new protected areas, effective *in situ* protection, enforcement of the laws, education for local people and fishermen, campaigns for raising public awareness, monitoring population parameters, and determining active habitats and overlapping administrative zones (between Turkey and Greece) in the Aegean Sea. In addition, at least one rehabilitation facility should be secured for effective care of orphaned or live stranding seals. Cooperation between Turkey and Greece in terms of research, legislation, education and protection is essential.

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ALIEN SPECIES INVADING THE AEGEAN SEA HABITATS─AN EASTERN SYNTHESIS

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1. Introduction

The introduction of species from one biogeographic region to another has been recognized as a major threat to ecosystems, with a set of ecological and evolutionary consequences from species to ecosystem levels (Grosholz, 2002; Ehrenfeld, 2010). Introduced species have different degree of impacts in the recipient area and can be classified as established, casual and invasive alien species according to their success of establishment and invasive potential (Zenetos *et al*., 2005). Invasive alien species that are capable of overcoming biotic and abiotic barriers in their new environments and have noticeable ecological and economic impacts are accepted one of the most serious threats to the conservation of natural resources (Lodge, 1993).

The Mediterranean Sea is considered as one of the hot-spot areas in terms of the alien species diversity (Çinar, 2013) and almost 1000 alien species have been reported from the region up to date, with the eastern basin being more prone to invasion than the western basin as it has more than one pathway for the introduction of the species (Zenetos *et al*., 2010). The most important pathway through which alien species have been continuously entering into the Mediterranean without any decisive filtering mechanism is the corridor, called Suez Canal. The majority of alien species (more than 70%-80%) reported from the eastern part of the Mediterranean Sea have been introduced into the area via the Suez Canal (called as Lessepsian species/invaders, Çinar *et al*., 2011; Zenetos *et al*., 2012). In July 2015, the Suez Canal has been greatly enlarged with the construction of a new canal paralleled to the older one. It was foreseen that this enlargement initiative would facilitate the entrance of more (so-called double) Lessepsian invaders to the Mediterranean Sea that might cause major, irreversible ecological and economic consequences in the region (Galil *et al*., 2015).

Having a great habitat richness and different environmental conditions between its northern and southern points, the Aegean Sea offers a suitable area for a variety of living forms and acts as a crossroad for the thermophilic and **psychrophilic** marine species (Kocataş and Bilecik, 1992). Its interaction with the Levantine Sea and Black Sea through different current systems, it represents a complex and dynamic ecosystem with additions of Indo-Pacific species predominantly drifting to the area by means of the Asian Minor current. Çinar *et al*., (2011) estimated that 58% of total number of alien species reported from the eastern Aegean Sea were the species first entered into the Mediterranean via the Suez Canal and expanded their distributional ranges to the Aegean Sea by natural dispersal processes.

This paper focuses on the alien species diversity along the eastern Aegean Sea coast and their actual impacts on the native biota.

2. History of studies on alien species in the area

The first alien species in the eastern Aegean Sea was reported by Quatrefages (1865), who reported the invasive serpulid species, *Hydroides dianthus* (cited as *Serpula uncinata*) in İzmir Bay. The other alien species's reports in the region were begun after the mid-20th century with the studies focusing on fishes by Tortonese (1947), Kosswig (1950), Ben-Tuvia (1966) and Geldiay (1969). After 1970, alien species other than fish were begun to be reported. Between 1970 and 1975, 5 algae, 2 crustaceans and 3 fish were recorded from the area. By the year 1975, the eastern Aegean Sea coast included 29 alien species (Figure 1). After 10 years later, the total number was increased to 40, mainly thanks to the studies by Marinopoulos (1979) and Zeybek *et al*. (1986). Almost a similar number of alien species (ca. 19 species) was reported along the Aegean coast at ten years intervals between 1965 and 1995. The first sharp increase in the number of recorded alien species was detected between 1995 and 2005, when the cumulative number of species by 1996 was doubled, bringing the number of species known from the area to 123. The main contributors (>4 species reports) within this interval were Meriç *et al*. (2004) and Okuş *et al*. (2004). During the last ten years (2005-2015), 99 new alien species (3 algae, 22 protozoans, 65 invertebrates and 9 fish) were reported from the Aegean coast of Turkey.

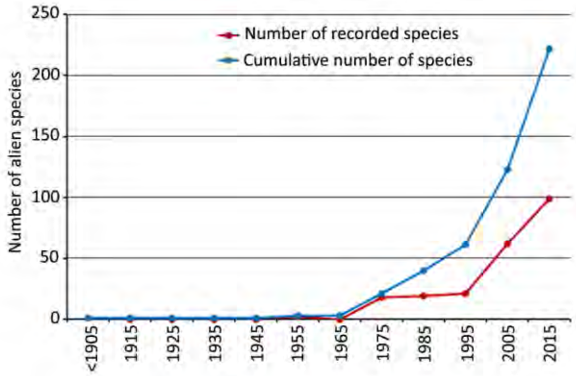

Figure 1. Yearly and cumulative changes in the number of new records of alien species along the eastern Aegean Sea.

3. Alien species along the eastern Aegean Sea

Up to date, a total of 222 marine alien species belonging to 13 systematic groups have been reported from the Aegean Sea coast of Turkey (Figure 2). Fifty-five species were added to the species list after the review paper by Çinar *et al*., (2011), who reported 167 (erroneously written as 165 species) species from the area (Table 1). There are two reasons for this high addition; 1) 24 species were escaped from the Çinar *et al*., (2011)'s attentions (records appeared in project's final reports and thesis were taken into account in the present study) and 2) 31 species were newly reported from the area. Alien ciliate and tunicate species were recently reported from the area. Yurga (2012) found a few number of specimens of two ciliates [*Leprotintinnus nordqvistii* and *Rhizodomus tagatzi* (cited as *Tintinnopsis corniger*)] in the middle part of Izmir Bay in 2007 and postulated that they might have been introduced to the area via ballast water of ships. The latter species was also reported from Gemlik Bay (Sea of Marmara) by Durmuş *et al*., (2011). Two alien ascidians (*Phallusia nigra* and *Microcosmus exasperatus*) were reported from the eastern Aegean Sea up to date. The black ascidian *P. nigra* occurred in Bodrum (Gözcelioğlu, 2011), and a few number of individuals of *M. exasperatus* were found in the polluted inner part of İzmir Bay (Ramos-Espla *et al*., 2013).

The taxonomic groups that are represented by higher number of alien species in the area are Pisces (40 species), Mollusca (39 species), Crustacea (34 species) and Protozoa (31 species) (Figure 2). Ctenophora (*Mnemiopsis leidyi*) and Spermatophyta (*Halophila stipulacea*) have only one alien species. Tunicata and Bryozoa had two alien species. Among algae, Rhodophyta possessed the highest number of alien species (12 species), followed by Heterokontophyta (7 species), Chlorophyta (7 species) and Cyanophyta (1 species). The majority of alien protozoon species belonged to Foraminifera (29 species). Among Cnidaria, Hydrozoa were represented by 5 alien species, Scyphozoa by 3 species and Anthozoa by 1 species (*Diadumene lineata*). Sedenter polychaetes (19 species) were represented by higher number of species than errant polychaetes (11 species). The majority of alien Crustacea species (18 species) are members of decapod crustacean. Among Mollusca, Gastropoda and Bivalvia had 26 and 13 species, respectively. No alien cephalod species was encountered in the Aegean Sea, whereas two species (*Octopus aegina* and *Sepioteuthis lessoniana*) were encountered along the Levantine coast of Turkey (Çinar *et al*., 2011). All alien fish species belonged to class Actinopteri.

Table 1. The new additions of alien species to the inventory of the Aegean coast of Turkey after the study by Çinar *et al*. (2011) and their first year of observations (FYO). ES: Establishment Success (E: Established, C: Casual, Cr: Cryptogenic), O: Origin (IP: Indo-Pacific, RS: Red Sea, EA: Eastern Atlantic; AT: Atlantic, WA: Western Atlantic, IO: Indian Ocean, PO: Pacific Ocean, CT: Circumtropical, Co: Cosmopolitan) MI= Mode of Introduction (Su: Suez Canal, S: Shipping, Aq: Aquaculture), H: Habitat [Hs: Hard Substratum (including algae and sponges), Ss: Soft Substratum (including phanerogames), P: pelagic, Pz: parasite], DR: Depth Range (I: 0–10 m, II: 11–50m, III: 51–100 m).

Alien Species	FYO	ES	O	MI	H	D
ALGAE						
Chlorophyta						
Caulerpa taxifolia (M.Vahl) C.Agardh, 1817	2010[1]	E	PO	S	Hs/Ss	I,II
Codium parvulum (Bory de Saint Vincent ex Audouin) P.C.Silva, 2003	2012[2]	E	PO	Su	Hs	I
Codium taylorii P.C.Silva, 1960	2011[3]	E	WA	S	Hs	I
PROTOZOA						
Foraminifera						
Acervulina inhaerens Schulze, 1854	2004[4]	E	IP	?S	Ss	I
Cymbaloporetta squammosa (d'Orbigny, 1826)	2002[5]	E	IP	?Su	?	I
Iridia diaphana Heron-Allen & Earland, 1914	2008[6]	E	IP	?S	?	I
Polymorphina fistulosa (Cushman, 1914)	2012[7]	E	IP	?S	Ss	I
Spiroloculina cf. *angulata* Cushman, 1917	2004[4]	E	IP	Su	?	I,II
Ciliata						
Leprotintinnus nordqvistii Brandt, 1906	2007[8]	E	?AT	S	P	I
Rhizodomus tagatzi Strelkow & Wirketis, 1950	2007[8]	E	?AT	S	P	I
CNIDARIA						
Hydrozoa						
Eudendrium merulum Watson, 1985	2000[9]	E	CT	?Su	Hs	I
Sertularia marginata (Kirchenpauer, 1864)	1977[10]	E	CT	?Su	Hs	I
Clytia linearis (Thorneley, 1900)	1977[10]	E	CT	?Su	Hs	I
Filellum serratum (Clarke, 1879)	1977[10]	C	CT	?Su	Hs	I
Scyphozoa						
Cassiopea andromeda (Forsskal, 1775)	2011[11]	E	RS/IP	Su	Ss,P	I
Phyllorhiza punctata Lendenfeld, 1884	2011[12]	C	RS	Su	P	I
Rhopilema nomadica Galil, Spanier & Ferguson, 1990	2011[13]	E	RS/IP	Su	P	I
Anthozoa						
Diadumene lineata (Verrill, 1869)	1997[14]	E	AT	S	Hs	I
POLYCHAETA						
Prosphaerosyllis longipapillata (Hartmann-Schröder, 1979)	2004[15]	E	PO	S	Ss	I,II
Ceratonereis mirabilis Kinberg, 1866	2011[16]	E	RS/IP	Su	Ss	III
Glycinde bonhourei Gravier, 1904	2009[17]	E	RS/IP	Su	Ss	I
Diopatra marocensis Paxton, Fadlaoui & Lechapt, 1995	2005[18]	E	AT	?S	Ss	I,II

CRUSTACEA						
Alien Species	**FYO**	**ES**	**O**	**MI**	**H**	**D**
Copepoda						
Calanopia elliptica (Dana, 1849)	1999[19]	?E	WA	S	P	I
Labidocera pavo Giesbrecht, 1889	1999[19]	E	IP	Su	P	I
Pseudocalanus elongatus (Boeck, 1865)	2000[20]	Cr	EA	S	P	I
Amphipoda						
Elasmopus pectenicrus (Bate, 1862)	1995[21]	C	CT	Su	Hs	I
Monocorophium sextonae (Crawford, 1937)	1995[21]	E	PO	S	Hs/Ss	II
Tanaidacea						
Paradoxapseudes intermedius (Hansen, 1895)	1976[22]	E	AT	?S	Hs, Ss	I,II
Decapoda						
Alpheus lobidens de Haan, 1849	2014[23]	C	IP/RS	Su	Ss	I
MOLLUSCA						
Gastropoda						
Alvania dorbignyi (Audouin, 1826)	2000[24]	Cr	Co	?	Ss	I
Rissoina bertholleti Issel, 1869	2001[25]	E	RS/IO	Su	Ss	I
Crepidula fornicata (Linnaeus, 1758)	2012[26]	E	AT	S	Ss	I,II
Retusa desgenettii (Audouin, 1826)	2002[27]	E	RS/IP	Su	Ss	I
Pyrunculus fourierii (Audouin, 1826)	2002[27]	E	RS/IP	Su	Ss	I
Monotygma lauta (Adams, A., 1853)	2014[28]	E	RS/IP	Su	Pz	I,II
Odostomia lorioli (Hornung & Mermod, 1924)	1995[29]	C	RS	?Su	Ss	I,II
Chelidonura fulvipunctata Baba, 1938	2004[30]	E	IP	?Su	Ss	I,II
Cylichnina girardi (Audouin, 1826)	1996[31]	E	IP	Su	Ss	II
Elysia tomentosa Jensen, 1997	2002[32]	E	?IP	?Su	Hs	I,II
Bivalvia						
Arcuatula senhousia (Benson in Cantor, 1842)	2012[33]	E	IP	S	Ss	I
Malleus regula (Forsskål in Niebuhr, 1775)	2002[32]	E	RS/IP	Su	Hs	I
Spondylus spinosus Schreibers, 1793	2002[32]	E	RS/IP	Su	Hs	I,II
Crassostrea gigas (Thunberg, 1793)	2001	E	PO	Aq	Hs	I
ECHINODERMATA						
Diadema setosum (Leske, 1778)	2014[35]	E	RS/IP	Su	Hs	I
TUNICATA						
Phallusia nigra Savignyi, 1816	2011[11]	E	RS/IP	Su	Hs	I,II
Microcosmus exasperatus Heller, 1878	2004[36]	E	RS/IP	Su	Hs	I
PISCES						
*Ostorhinchus fasciatus (*White, 1790)	2011[37]	E	RS/IP	Su	Ss	I,II
Rachycentron canadum (Linnaeus, 1766)	2013[38]	C	CT	Su	P	II,III
Alien Species	**FYO**	**ES**	**O**	**MI**	**H**	**D**
Nemipterus randalli Russell, 1986	2011[37]	E	RS/IP	Su	Ss	I,II
Champsodon nudivittis (Ogilby, 1895)	2010[39]	E	IP/IO	?Su	Ss	II,III
Champsodon vorax Günther, 1867	2014[40]	C	IP/IO	?Su	Ss	III
Callionymus filamentosus Valenciennes, 1837	2010[41]	C	RS/IP	Su	Ss	II
Platax teira (Forsskål, 1775)	2006[42]	C	RS/IP	Su	Hs	II
Cynoglossus sinusarabici (Chabanaud, 1931)	2014[41]	C	RS/IP	Su	Ss	II
Torquigener flavimaculosus Hardy & Randall, 1983	2014[41]	C	RS/IP	Su	Ss	II

1. Turan *et al*., 2011; 2. Aydoğan and Taşkın, 2015; 3. Taşkın and Aydoğan, 2012; 4. Meriç *et al*., 2008a; 5. Meriç *et al*., 2008b; 6. Meriç *et al*., 2010; 7. Meriç *et al*., 2012; 8. Yurga, 2012; 9. Marques *et al*., 2000; 10. Marinopoulos, 1979; 11. Gozcelioğlu, 2011; 12. Gulşahin and Tarkan, 2012; 13. Gulşahin and Tarkan, 2011; 14. Sarı *et al*., 2001; 15. Çinar *et al*., 2014a; 16. Çinar and Dagli, 2012; 17. Çinar *et al*., 2012; 18. Çinar *et al*., 2014b; 19. Aker, 2002; 20. Benli *et al*., 2001; 21. Doğan *et al*., 2008; 22. Kocataş, 1976; 23. Bakir *et al*., 2015; 24. Erol-Özfuçucu *et al*., 2003; 25. Koçak and Katağan, 2005; 26. Doğan *et al*., 2014; 27. Crocettaand Tringali, 2015; 28. Öztürk *et al*., 2014; 29. Öztürk *et al*., 2013; 30. Okuş *et al*., 2006; 31. Buzzurro and Greppi, 1996; 32. Okuş *et al*., 2004; 33. Doğan *et al*., 2014; 34. Doğan *et al*., 2007; 35. Yapici *et al*., 2014; 36. Ramos-Espla *et al*., 2013; 37. Bilecenoğlu and Yokeş, 2013; 38. Akyol and Ünal, 2013; 39. Filiz *et al*., 2013; 40. Aydın and Akyol, 2015; 41. Bilecenoğlu *et al*., 2014; 42. Bilecenoğlu and Kaya, 2006.

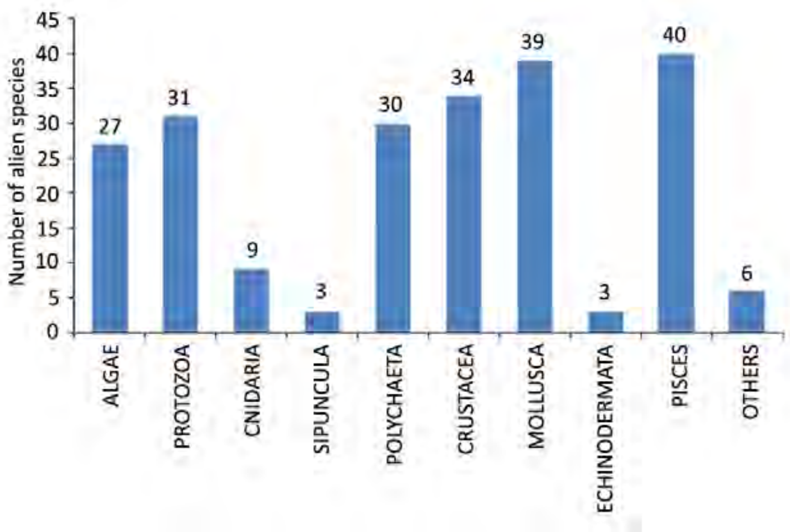

Figure 2. The number of alien species in taxonomic groups.

More than 80% of the alien species have become established in the eastern Aegean Sea, 24 species are casual and 12 species are cryptogenic (Figure 3). The occurrences of three algae (*Acanthophora muscoides*, *Polysiphonia kampsaxii* and *Sargassum latifolium*) and two polychaete (*Podarkeopsis capensis* and *Sigambra parva*) species are questionable in the area. Among the established species, 71 species seem to be invasive or potentially invasive species.

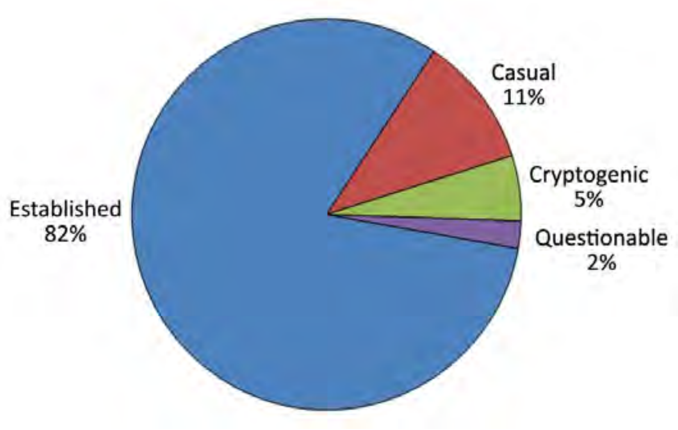

Figure 3. The percentages of alien species's categorizations.

4. The origins and introduction pathways of alien species

The majority of species (160 species, 72% of total number of species) found along the eastern Aegean coast were originated from the Indo-Pacific/Red Sea areas (Figure 4). The Atlantic-originated species comprised 14% of the number of species. The circumtropical species were represented by 21 species in the area. The origins of eleven species, mainly algae, are unknown.

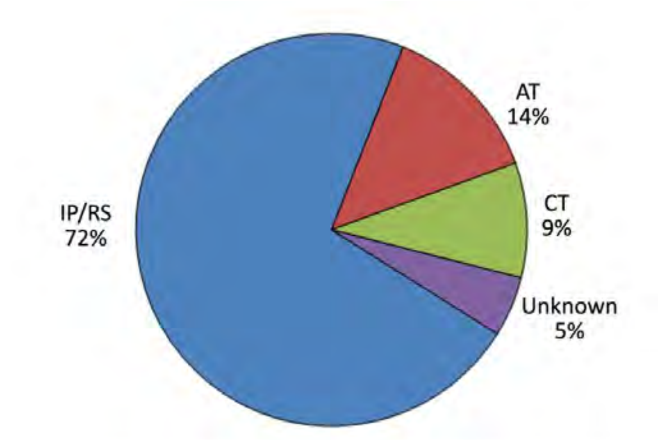

Figure 4. The origins of alien species reported from the eastern Aegean Sea. IP/RS: Indo-Pacific/Red Sea, AT: Atlantic, CT: Circumtropical.

Being a neighbor on the Levantine Sea, the Aegean Sea receives high number of alien species that were entered into the Mediterranean Sea from the Red Sea via the Suez Canal (Lessepsian invaders). A total of 136 Lessepsian invaders (61% of total number of alien species) were found along the eastern Aegean Sea (Figure 5). Species introduction via shipping comprised 35% of total number of alien species in the area. The introductions of three species (*Crassostrea gigas*, *Ruditapes philippinarum* and *Liza haematocheila*) were attributed to escapes from the aquaculture facilities. They extended their distributional ranges to other Mediterranean and Black Sea environments later on. It is a requisite to re-evaluate if the eastern Atlantic species that were entered into the Mediterranean Sea via Gibraltar are alien species, as no anthropogenic vectors are involved in their introductions. Two fish (*Enchelycore anatina* and *Sphoeroides pachygaster*) and one decapod crustacean (*Processa macrodactyla*) species were claimed to have been introduced to the Mediterranean via Gibraltar. As *E. anatina* solely occurs in the eastern Mediterranean, Gibraltar as a pathway (corridor) for the introduction of this species seems to be unlikely, but an anthropogenic vector such as shipping or aquarium release could be incorporated with the introduction of this species to the eastern part of the Mediterranean. However, *S. pachygaster* and *P. marcodactyla*, which are distributed along the eastern Atlantic coasts, might have been naturally entered into the Mediterranean Sea and expanded their distributional range within the basin, so they could be accepted as native rather than alien species. Their first reports came from the Alboran Sea, suggesting their entrance to the Mediterranean by means of natural dispersal mechanism. However, we kept these species in the list at time being and will re-evaluate their alien status in the future.

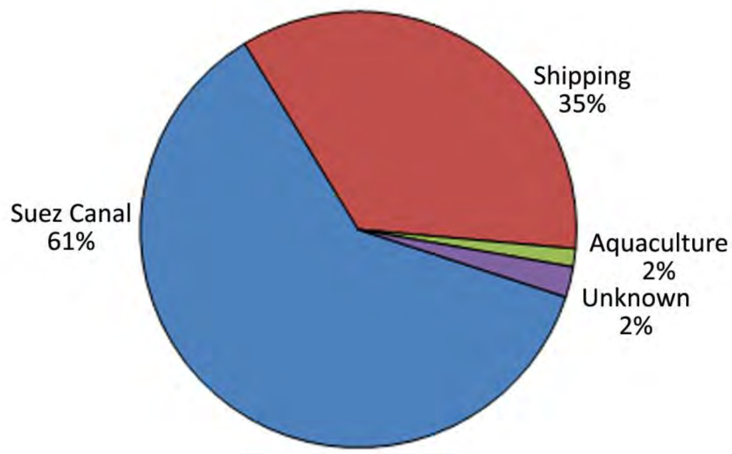

Figure 5. The relative importance of pathways for the introduction of alien species to the eastern Aegean Sea.

The percentages of Lessepsian invaders vary among the taxonomic groups. For instance, Lessepsian invaders comprised 100% of total number of species in Echinodermata; 93% in Pisces; 88% in Cnidaria; 65% in Foraminifera. Ship-mediated species are important in polychaetes and algae, accounted for up to 70% and 55% of total number of alien species, respectively.

5. Habitat and depth preferences of alien species

The highest number of alien species were encountered on soft (83 species, 37% of total number of species) and hard substrata (65 species, 29%). Twenty-nine alien species were common on hard and soft substrata. All jellyfish and copepods, and some fish (nine species) occurred in the pelagic environment. Two pyramidellid gastropods (*Monotygma fulva* and *M. lauta*) are known to be parasite on some echinoderms and bivalves (Öztürk *et al*., 2014). The habitats of 23 alien species (mainly foraminiferans) were unknown.

Majority of alien species were found in association with shallow water-benthic habitats (0-50 m) (Figure 6). Thirty-three species were found at depths deeper than 100 m. Fourteen alien species were capable of occurring at depths between 101 and 200 m. *Sphoeroides pachygaster* has the widest depth distributional range, inhabiting depths from 0 to 400 m.

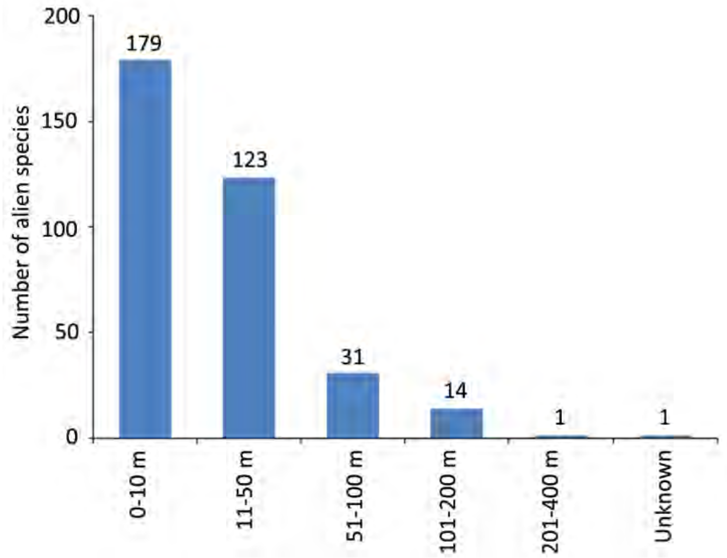

Figure 6. The depth preferences of alien species along the eastern Aegean Sea.

6. Invasive alien species and their impacts

According to the Zenetos's (2012) classification of invasive alien species in the Mediterranean Sea, the species list of the eastern Aegean Sea included a total of 71 invasive or potentially invasive species. Majority of these species have become highly invasive along the Levantine coast of Turkey, but a few number of them have sustained a proliferated population and become invasive species in habitats of the Aegean Sea. Higher numbers of invasive species (mainly polychaetes) were reported from the polluted inner part of Izmir Bay, where 6 polychaete (*Streblospio gynobranchiata*, *Polydora cornuta*, *Prionospio pulchra*, *Pseudopolydora paucibranchiata*, *Hydroides elegans* and *H. dianthus*), 1 crustacean (*Metapenaeus affinis*) and 1 mollusc (*Anadara transversa*) species invaded the soft and hard substrata in the area. The invasive polychaetes comprised more than 90% of total zoobenthic populations in the majority of samples collected at some sites near Alsancak Harbour (Çinar *et al*., 2006; Dağlı and Çinar, 2008; Dağlı *et al*., 2011). The population densities of *H. elegans* and *S. gynobranchiata* reached up to 111,000 ind.m^{-2} and 61,000 ind.m^{-2} in the area, respectively (Çinar *et al*., 2006; 2008).

High number of individuals of the jinga shrimp *Metapenaeus affinis* were caught with a trammel net set in a muddy bottom at depths 8−12 m in the inner part of Izmir Bay in 2008 (Aydın *et al*., 2009). As its distribution was only confined to Alsancak Harbour and its vicinity, its introduction to the area via ballast water of ships was hypothesized. Although the inner part of Izmir Bay is banned for any fishing activity, illegal fishing of this shrimp in the area is still continuing and it coasts ca. 35 ₺/per kg in the market. As the shrimp is highly demanded by local consumers, it was said that local fishermen had translocated it outside İzmir Bay (Aliağa) to fish it outside the banned area, but no documented report is available regarding its presence outside the inner part of Izmir Bay yet.

Anadara transversa is a dominant component of benthic communities in the inner and middle parts of the İzmir Bay (Çinar *et al*., 2006). The identification of this species in the area has a long story. It was begun when Dr. Ahmet Kocataş (Ege University, İzmir) sent a large number of the arcid specimens to Dr. Muzaffer Demir (İstanbul University, İstanbul) in spring 1978, who was the expert of this group in Turkey at that time. After a long examination, he quoted "*it could be either* Arca (Scapharca) transversa *Say, 1822 or* Arca (Scapharca) amygdalum *Philippi, 1847. However, I was not able to decide which one it was*" and then he sent some specimens to Dr. B. Metivier at Museum d'Histoire Naturelle (Paris) and he finally identified them as *A*. (*S*.) *amygdalum* (Demir, 1977). However, this species name for the Mediterranean population of the species was used for a short time. A new name *Scapharca demiri* was proposed for *Arca amygdalum* since this name was pre-occupied for other species of *Arca* (Piani, 1981). Thanks to molecular tools, Albano *et al*. (2009) postulated that the specimens previously identified as *S. demiri* in the Adriatic, Greece and Turkey in fact belonged to *A. transversa*, a common species of the eastern coasts of North America. *Scapharca demiri* then became a junior synonym of *A. transversa*. This species prefers inhabiting semi-polluted bottom of İzmir Bay. Demir (1977) reported that it occurred dominantly in gray-muddy bottom (300 ind.m^{-2}) and became scarce in areas where sediment colour was turned into black because of high organic inputs (30 ind.m^{-2}).

Çinar *et al.* (2006) found a high density of this species (580 ind.m^{-2}) near the boundary between the middle part and inner part of İzmir Bay.

The invasive green alga *Caulerpa cylindracea* is one of the invasive species that has a wide distributional range along the eastern Aegean Sea, occurring throughout the coastline from Dalaman River to the entrance of Çanakkale Strait (Çinar *et al*., 2005), but it covers large benthic areas at some localities such as Ildırı Bay, where intense fish farming activities take place. It has invaded both soft and hard substrata and extended to depths from shallow water down to 40 m. Not only does it cover many habitats (such as *Posidonia oceanica* meadows, bare sand, rocks) like a carpet, but also it blocks pores of many sponge species with its elongated stolons and rhizoids, eventually resulting in mass deaths or local necrosis (personal observation MEÇ, Figure 7). Ulas *et al*. (2012) found that biomass of *C. cylindracea* increased with increasing depth in İzmir Bay and its biomass (635 g.m^{-2}) estimated at 25 m depth were five times higher than those at 5 m depth.

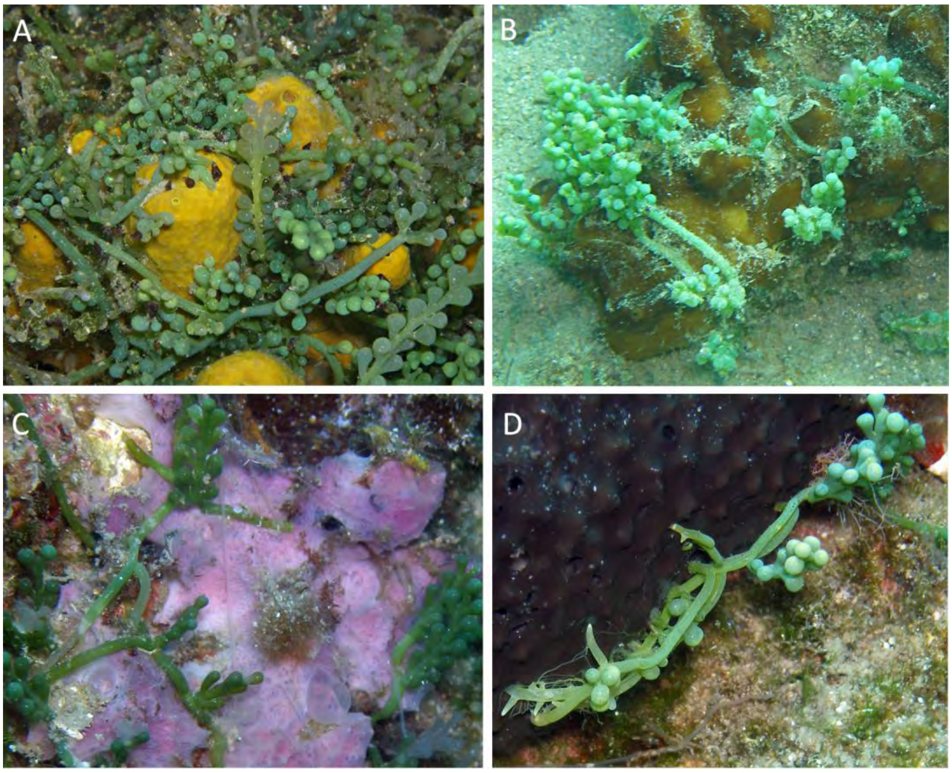

Figure 7. The sponge specimens densely colonized by the invader *Caulerpa cylindracea* in Ildırı Bay. A. *Aplysina aerophoba*, B. *Chondrilla nucula*, C. *Dysidea avara*, D. *Sarcotragus spinosulus* (Photographed by Melih Ertan ÇINAR).

The killer alga *Caulerpa taxifolia*, which was unintentionally released from the Oceanography Museum of Monaco to the western Mediterranean and become established in the area in 1984 (Meinezs and Boudouresque, 1996), was reported for the first time in the Aegean Sea by Turan *et al*. (2011). This species was found in summer 2010 in Yolluca Social Facility Command belonging to the Turkish Navy Forces located near Çeşmealtı Port and covered an area of 35 m^2. The morphology of this species is similar to *Caulerpa taxifolia* var. *distichophylla*, which were first reported in İskenderun Bay within the Mediterranean Sea (Çevik *et al*., 2007). However, it was claimed that the alga found in İzmir Bay belonged to the western Mediterranean strain of *C. taxifolia* (G. Turan, pers. comm.). We do not know at this stage if it still occurs in the area or has a potential to invade the benthic habitats like in the western Mediterranean. For this, a monitoring study is urgently required.

The phanerogame *Halophila stipulacea* is one of the successful invaders in the Aegean Sea. It forms dense beds in some areas like Ildırı Bay (MEÇ, personal observation) and extended its northern limit around Dikili (Akçalı and Cirik, 2007). Its impact on the native biota has not been a subject of study in the eastern Aegean Sea.

Hot water springs along the coast of Kuşadası attracts dense settlements of some alien foraminiferan species. *Amphistegina lobifera* formed a dense population density near the spring (1954 specimens per 5 g of sediment) and its density sharply decreased when moving away from the spring (Meriç *et al*., 2010). This species also covered coralligenous habitats in Ildırı Bay (personal observation, MEÇ). It has a wide distributional range in the area and also occurs in the Sea of Marmara (Çinar *et al*., 2011).

A single specimen of *Rhopilema nomadica*, which constitutes great swarms almost in each summer in the Levantine Sea, was recently reported from Gökova Bay (Gulsahin and Tarkan, 2011). One specimen of this species was also captured in the inner part of İzmir Bay in 2003 (MEÇ, unpublished record). Though it is an invasive species along the Levantine coasts and has great impacts on human health and fisheries by obstructing fishing nets and covering catches with their stinging mucous, it can be classified as a casual alien species along the eastern Aegean Sea at the time being. We do not know if it will form a massive bloom in the colder water of the Aegean Sea in the future. The other jellies such as *Cassiopea andromeda* and *Phyllorhiza punctata* were also represented by a few number of specimens along the Aegean Sea (Gözcelioğlu 2011; Gulsahin and Tarkan 2012). The former species extended its distributional range to Güllük Bay (Özgür Özbek and Öztürk 2015).

The siganids *Siganus rivulatus* and *S. luridus* were reported from the southeastern Aegean Sea more than 40-60 years ago, but they have not formed dense populations in the area. It is possible to observe siganid schools (both species) from Marmaris to entire

Datça coasts up to Bodrum (personal observations, MEÇ+MB), which swiftly decrease towards Kuşadası. It was only *S. rivulatus* that extended its distribution to northern Aegean Sea (Çandarlı Bay) (Bilecenoğlu, 2010).

A total of 5 alien fish species (*Lagocephalus sceleratus*, *Lagocephalus spadiceus*, *Lagocephalus suezensis*, *Torquigener flavimaculosus* and *Sphoeroides pachygaster*) belonging to the family Tetradontidae have been reported from the eastern Aegean Sea. They are known as puffer fish and have impacts on fishing activities, human health and socio-economic aspects in the eastern Mediterranean, especially in the Levantine Sea. Among them, *L. sceleratus* was more successful invader in the Aegean Sea, and its northern distributional limit has reached to Behramkale (Edremit Bay) in 2008 (Türker-Çakır *et al*., 2009). However, the reports of puffer fish in the area were limited with a few numbers of species and there is no sign that they have obvious impacts in the area.

7. Conclusions

The rate of introduction of alien species has been exacerbated by on-going climatic changes and increased shipping traffics in the wave of capitalisms around the globe. Marine ecosystems have been largely influenced or altered by anthropogenic disturbances, making them more vulnerable to any kind of additional pressures like the introduction of invasive alien species. To protect the nature, it is essential to understand its functioning and reactions to changing environments in order to take effective precautions. The only way to do it is to set a long-term monitoring programme for assessing the distribution of alien species and their actual and possible impacts. It should be kept in mind that impacts of invasive species change greatly among habitats and ecosystems in the recipient region, and that many obvious impacts only become more evident long after the onset of invasion.

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BLUEFIN TUNA FISHING FOR FARMING AND MANAGEMENT IN THE AEGEAN SEA

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1. Introduction

Atlantic Bluefin tuna (*Thunnus thynnus* - ABFT) is an epipelagic and mesopelagic tuna species which has transatlantic migrations. They have properties for adapt to different environments from polar regions to tropical by way of decreasing the rate change in the internal temperature and thermoregulation system allowing the temperature rise due to increasing metabolism (Lutcavage *et al*., 1997). ABFT is distributed throughout the Atlantic Ocean, as well as in the Gulf of Mexico and the Mediterranean Sea.

Aegean Sea which is one of the three large areas of eastern Mediterranean is its mainly feeding ground in winter and early spring (Damalas and Megalofonou, 2012). After spawning, some of the tagged ABFT from Eastern Mediterranean migrate to Aegean Sea (De Metrio *et al.,* 2004; 2005) and intense fishing operations in this region between October and April in 1990's (Karakulak and Oray, 1995; Oray and Karakulak, 1997; Karakulak, 1999) have shown that Aegean Sea is the important feeding ground after spawning activities.

ABFT is located among the most demanding fish in the world. Besides being an important part of daily diet for millions of people, it is the basic material of luxury sushi and sashimi market. Among Mediterranean commercial fishery species, the most important large pelagic is ABFT. It has been exploited in the Mediterranean basin for many decades. With the establishment of ABFT farm on the Aegean Sea in 2002, it has become even more economically important.

2. ABFT Fisheries in the Aegean Sea

Since mid-1980, ABFT fishery in the Mediterranean has increased to respond to the high prices and growing demand in Japanese market (Figure 1). Similarly, increasing has been seen in ABFT fishery in the Aegean Sea performed by Turkish and Greek fishermen. In 1957, annual catch was 800 tonnes in Turkish waters. However, this amount advanced to 2459 t in 1990 and 5899 tonnes in 1998. After this year, the tendency towards reduction ABFT catches was observed due to fishing quota implementation of The International Commission for the Conservation of Atlantic Tunas (ICCAT). The ABFT fishery in Greek waters has ranged between 400-1200 tonnes during the 1950-1960s. Fishery has declined too much in 1970s. Since the mid-1980s fishery has increased again and reached 1217 tons in 1996, but decreased continuously to around 176 tonnes due to catch regulations in 2012 (ICCAT, 2014a).

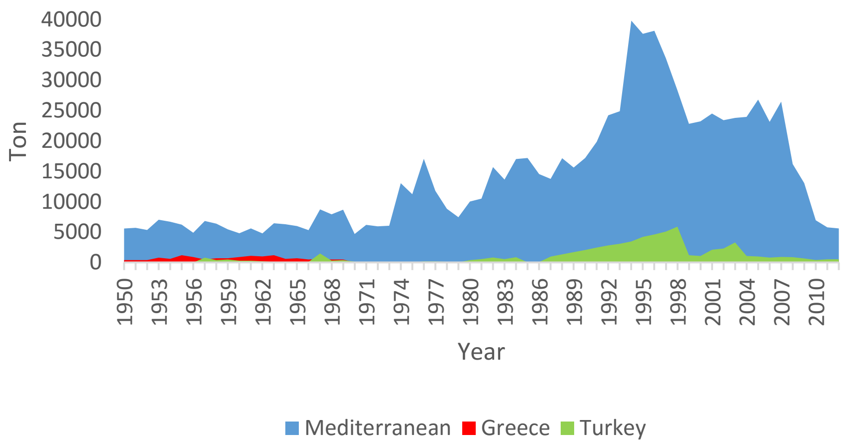

Figure 1. Catches of ABFT in the Mediterranean Sea (Greece and Turkey)

In the Aegean Sea, ABFT is caught by means of several fishing gears: purse seine, longlines, hand lines, gillnet and harpoon (Figure 2). Turkish fishermen generally use purse seines. A small portion of the Turkish fishery is taken as by-catch in the swordfish and other tuna fisheries. In Greece, ABFT catch has been mostly provided by longlines and hand lines (ICCAT, 2014a). However, ABFT is also caught in Greece by various other gears (albacore and swordfish longlines, clupeoid purse seine, traps) as a by-catch. In 2010, the number of purse seine fishing vessels of ABFT fishery consisted of 18 purse seine vessel in Turkey (>20 m), 37 purse seine, 52 longline and 135 hand lines vessels in Greece (<24 m, generally 10-15 meters) (ICCAT, 2012; Karakulak *et al*., 2012). Another important coastal fishery in the Aegean Sea is gillnet fishing (Karakulak *et al.,* 2007; Akyol *et al.,* 2008; Ceyhan *et al.,* 2011). However, it has been curtailed significantly after the United Nations, General Fisheries Commission for The Mediterranean (GFCM) and ICCAT Recommendations and Resolutions to ban drift gillnets. Although its catches are minor, harpoon fishery exists in the North Aegean coast of Turkey and EU Greece.

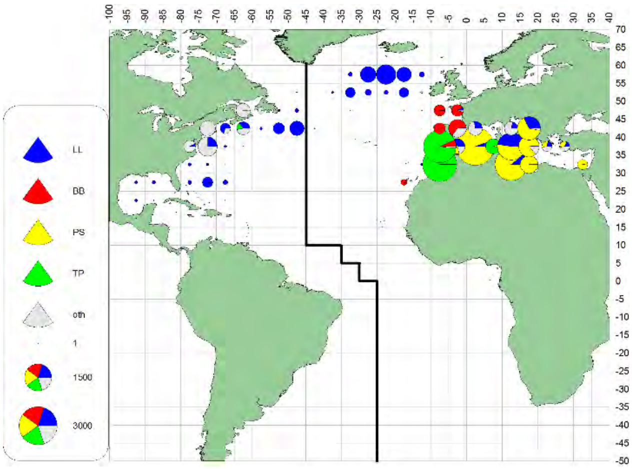

Figure 2. ABFT fishing areas with respect to main gears from 2010 to 2012 (LL-longline, BB-bait boat, PS-purse seine, TP-trap and OTH-other fishing gear) (ICCAT, 2012).

In 1990s, Turkish purse seiners have intensively produced to ABFT fishery in the Aegean Sea depending on the reduction of anchovy fishery in the Black Sea and fishing fields have been expanded over time (Mert *et al.,* 2000; Karakulak and Oray, 2009). The important fishing ports of Turkish ABFT purse seiners are; Çanakkale, Kabatepe, Odunluk, Küçükkuyu, Babakale, Gülpınar, Küçükkuyu, Altınoluk, Aliağa, Çandarlı, Yenifoça, Dikili, Alaçatı, Kuşadası, Güllük (Karakulak and Oray, 1995; Oray and Karakulak, 1997; Öztürk *et al.,* 2002). For Greek ABFT fleet, the most important are the ports of Kavala, N.Skioni, P.Cufo, Ierisos, Alonisos and Katerini in the northern Aegean Sea as well as Kimi, Kalymnos, Korfos, Epidauros, Chania in central and southern Aegean Sea (Liorzou, 2000) (Figure 3).

ABFT purse seine fishing in the Aegean Sea was carried out during the autumn, winter and spring (mainly between October and April) in the northern Aegean Sea and in the southern Aegean Sea (Karakulak, 1999; Karakulak, 2004; Karakulak, 2012). Handline fishing for ABFT concentrated during October and November in the northern Aegean Sea. Harpoon and gillnet were used in May-July (Liorzou, 2000).

In the 2000s, beginning of tuna farms operation completely done for the purpose of fattening in Turkey and Greece, however, ICCAT fisheries regulations have resulted changes in ABFT fishing period and grounds and the type of the fishing gear in the Aegean Sea. Turkish and Greek fishermen use mainly purse seine nets for ABFT fishing. ABFT is also caught by other gears as a by-catch. Turkish purse seine fleets has carried out fishing in the Levant Sea fishing grounds (Karakulak and Oray, 2009). Greek purse seine fleets are conducted at the Central Mediterranean fishing grounds between Malta and Libya and in the Ionian Sea (Tzoumas *et al.,* 2010). The fishing period is between May and June according to ICCAT fisheries management.

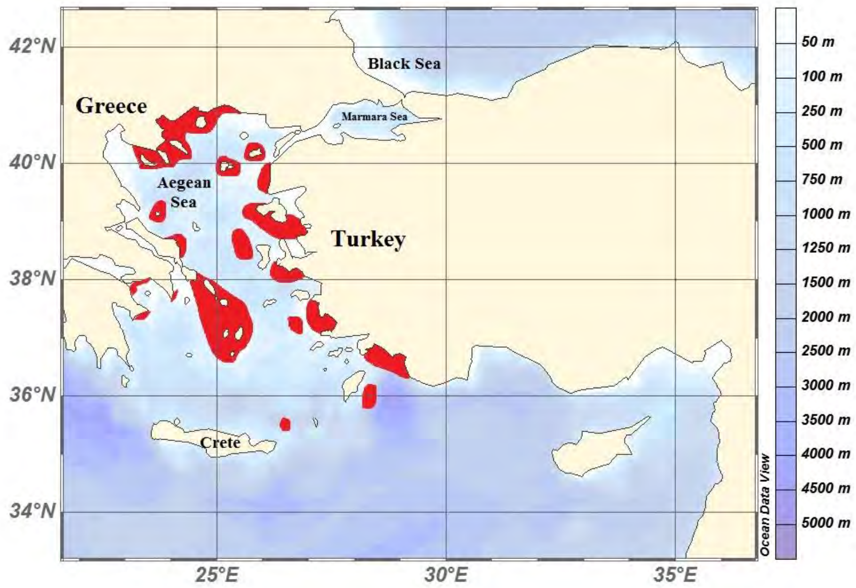

Figure 3. Important ABFT fishing areas in the Aegean Sea (Liorzou, 2000; Öztürk *et al*., 2002)

3. ABFT Farming in the Aegean Sea

Almost entire farmed ABFT have been exported to Japan, the largest importer in the World. Therefore, ABFT companies are an employment opportunity to local community and as well they have created foreign currency inflow to country where fattening is performed.

In Aegean Sea, ABFT farming started in Turkey in 2002 with two companies (Karakulak, 2007). In 2015, the six production centers on the ICCAT list for Turkey are concentrated in Izmir (In central Aegean Sea) (ICCAT, 2015a). In Greece, capture-based aquaculture of ABFT began in the 2003. The two on growing centers for ABFT on the ICCAT list. One of them is in the Echinades Islands (Ionian Sea), another is in Creta (Aegean Sea). Total capacity of all ABFT companies are 7240 tonnes in the Aegean Sea (Table 1) (Martín, 2007; ICCAT, 2015a). Activities of these ABFT companies (Figure 4) have been carried out depend on the total available catch quota assigned by ICCAT. Companies have exported alive ABFT from other Mediterranean countries in order fill to their capacity and have imported them by feeding (5-6 months) within cages.

Table 1. Numbered of registered ABFT farming in the Aegean Sea in 2015 (ICCAT, 2015a).

Country	Company Name	Location	Capacity (tonnes)
EC Greece	Poseidon Tuna Hellas S.A.	Messaras Gulf Prefecture of Herakleion	1100
Turkey	Akua Group Su Ürünleri A.Ş.	Ildır Village, Çifteadalar, İzmir	800
Turkey	Akua Group Su Ürünleri A.Ş.	Gerence Bay, Karaburun, Çeşme, İzmir	800
Turkey	Kılıç Deniz ürünleri İth.İhr. A.Ş.	Toprak Ada Village, Karaburun, İzmir	1840
Turkey	Kemal Balıkçılık A.Ş.	Toprak Ada, Karaburun, İzmir	1000
Turkey	Ak Tuna Gemicilik Balıkçılık Turizm ve Dış Tic. Ltd.Şti.	Küçükbahçe Village, Sivriburun, Karaburun, İzmir	1000
Turkey	Başaranlar Su Ürünleri Yetiştiriciliği San. Ve Tic. Ltd. Şti.	Sığacık Bay, Urla, İzmir	700

Concentration of farming activities in the Aegean Sea sometimes has caused to conflicts between farms and tourism sector. Pollution caused from touristic activities in the Aegean is well known. Existence of toxic pollution from ABFT farms originated by feeding has been also noted but there is no exact figure throughout the Mediterranean Sea (Tudela, 2002). However, in the case of keeping the ABFT in the cages for less time, it is also assessment that ecosystem might be renewed faster (Ottolenghi, 2008).

Although increasing has been seen in nitrate, ammonia and phosphate during production process as a result of a study conducted in Gerence Bay (İzmir, Turkey), it has been indicated that obtained data could not exhibit the environmental impact of ABFT farms because of high current values in ABFT farming areas and distance of this area from land (Aksu and Kaymakçı-Başaran, 2010).

All of caught ABFT have been collected within farms. By the reason of knowledge of ABFT farming is scarce, calculation of total production amount obtained from ABFT farming is also difficult. This is because, initially biomass and length-weight information cannot be calculated exactly because of growth and death rates of fish placed in cage is not certain (Miyake *et al.,* 2010). This situation causes mistakes in the calculation of stock.

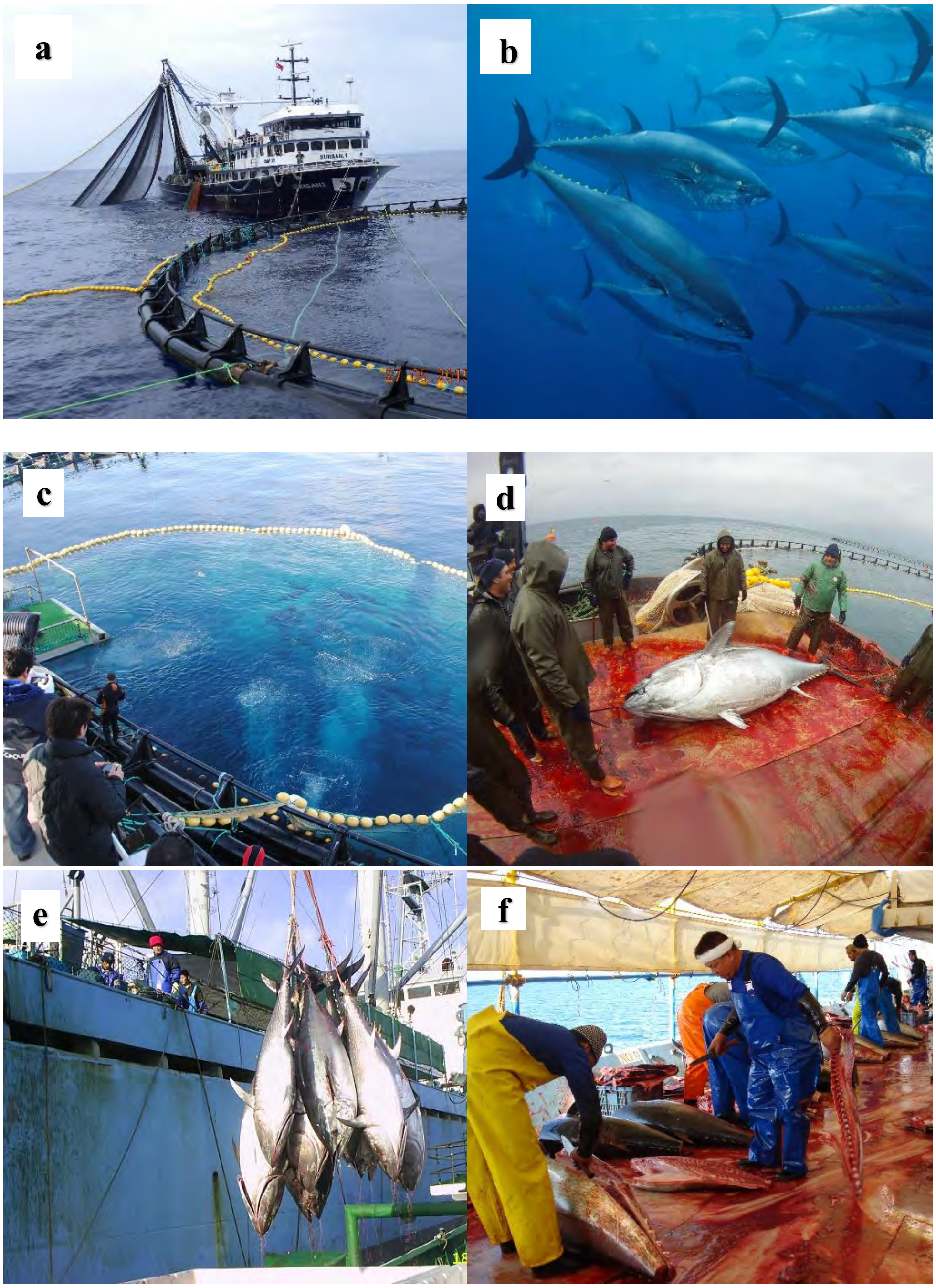

Figure 4. a) Transferring of ABFT caught with purse seines to cages b) ABFT in the cage c) Harvesting of ABFT d) One killed ABFT in harvesting time e) Far Eastern cruise ships purchase ABFT on the farm f) Cut ABFT into fillets are kept in the freezer.

4. ABFT Management in Aegean Sea

64. article of United Nations Convention on Law of the Sea- UNCLOS (1982) has indicated that the coastal State and other States whose nationals fish in the region for the highly migratory species shall cooperate directly or through appropriate international organizations with a view to ensuring conservation and promoting the objective of optimum utilization of such species throughout the region, both within and beyond the exclusive economic zone.

Because of the fact that ABFT is a highly migratory species, fisheries management has been done by an international commission and it is been protected. ICCAT is the international governing authority for ABFT. ICCAT was established in 1966 for the conservation of tunas and tuna-like species in the Atlantic Ocean and its adjacent seas. There are currently 50 contracting parties (ICCAT, 2015b). Greece and Turkey which are fishing for ABFT in the Aegean Sea became a member of ICCAT in 1997 and 2003, respectively. The Commission is responsible for collecting and analyzing statistical information and making recommendations. Each member country is responsible for implementing ICCAT management domestically.

ABFT are managed as two separate stocks; a western stock and eastern stock, separated at 45ºW longitude. Management regulations applied to ABFT fisheries in the Aegean Sea are the same as those of the Eastern Atlantic and Mediterranean area. Consequently, there is no partial stock assessment of ABFT.

ICCAT has implemented a conversation plan starting in 2007 and continuing through 2022 with the goal of achieving B_{MSY} with at least 60% probability for member states whose vessels have been actively fishing for ABFT in the eastern Atlantic and Mediterranean (ICCAT, 2014b). Important articles of this conservation plan are represented below.

1. The total allowable catches (TACs) are set at 16,142 t for 2015, 19,296 t for 2016 and 23,155 t for 2017. Allocation scheme of TAC by countries was given in Table 2.

Table 2. ABFT fishing quotas by country (for eastern Atlantic and Mediterranean stocks)

Countries	Quota 2015 (t)	Quota 2016 (t)	Quota 2017 (t)
Albania	39.65	47.40	56.91
Algeria	169.81	202.98	243.70
China	45.09	53.90	64.71
Egypt	79.20	94.67	113.67
European Union	9372.92	11203.54	13451.36
Iceland	36.57	43.71	52.48
Japan	1345.44	1608.21	1930.88
Korea	95.08	113.66	136.46
Libya	1107.06	1323.28	1588.77
Morocco	1500.01	1792.98	2152.71
Norway	36.57	43.71	52.48
Syria	39.65	47.40	56.91
Tunisia	1247.97	1491.71	1791.00
Turkey	657.23	785.59	943.21
Chinese Taipei	48.76	58.28	69.97
TOTAL	**15821**	**18911**	**22705**

2. The necessary measures shall be taken by each member state to ensure that the fishing effort of catching vessels and traps are commensurate with the fishing opportunities on ABFT available in the eastern Atlantic and Mediterranean Sea. The measures shall include for catching vessels over 24 m by establishing individual quotas.

3- Each member state shall also reserve a specific quota for the purpose of sport and recreational fisheries.

4- The permitted period by purse seine fishing is from 26 May to 24 June for ABFT in the eastern Atlantic and Mediterranean.

5- ABFT fishing by large-scale pelagic longlines shall be permitted in the eastern Atlantic and Mediterranean during the period from 1 January to 31 May.

6- Recreational and sport fishing for ABFT shall be permitted in the eastern Atlantic and Mediterranean from 16 June to 14 October.

7- The necessary measures shall be taken by member states to prohibit catching, retaining on board, transshipping, transferring, landing, transporting, storing, selling, displaying or offering for sale ABFT weighing less than 30 kg or with fork length less than 115 cm.

8- A minimum landing size for ABFT weighing less than 8 kg or with fork length less than or 75 cm fork length shall apply to the following situations:
    - ABFT caught in the eastern Atlantic by bait boats and trolling boats,
    - ABFT caught for farming purposes in the Adriatic Sea,
    - ABFT caught in the Mediterranean Sea by the coastal artisanal fishery for fresh fish by baitboats, longliners and handliners.

9- An incidental catch of maximum 5% of ABFT weighing between 8 and 30 kg may be authorized for catching vessels and traps fishing actively.

10- ABFT exceeding more than 5% of the total catch (by weight or number of pieces) of vessels not fishing actively are not authorized to retain at any time, All by-catches must be deducted from the quota of the flag State.

11- Each member state shall regulate its fishing capacity to provide that it is proportional to its allocated quota.

12- Each member state shall limit its tuna farming capacity to the total farming capacity of the farms that were registered in the ICCAT list or authorized and declared to ICCAT as of 1 July 2008.

13- Member states shall implement a vessel monitoring system for their fishing vessels over 24 m. This measure shall be applied for their fishing vessels over 15 m from 1 January 2010.

14- Each member states provide coverage by observers, issued with an official identification document, on vessels and traps active in the ABFT fishery on at least:
    - 20% of active pelagic trawlers (over 15 m)
    - 20% of active longline vessels (over 15 m)
    - 20% of active bait boats (over 15 m)
    - 100% of towing vessels
    - 100% of harvesting operations of bluefin tuna traps.

15- The observer performs in particular the following tasks: monitor fishing vessel compliance with the present recommendation, record and report upon the fishing activity, which include the following,
    - catch amount (including by-catch) also include species composition such as retained on board or discarded dead or alive,
    - area of catch (as latitude and longitude),
    - fishing effort/measurement/unit(number of hooks, number of sets etc.),
    - catch date

    Observe and estimate catches and verify entries made in the logbook, sight and record vessels that may be fishing contrary to ICCAT conservation measures.

16- Each member state takes the necessary measures to ensure that the video records belonging to farms and fishing vessels are made available to the ICCAT inspectors and ICCAT observers.

17- Consistent with their rights and obligations under international law, exporting and importing member states take the necessary measures for following cases:

- to prohibit domestic trade, landing, imports, exports, placing in cages for farming, re-exports and transhipments of eastern Atlantic and Mediterranean ABFT species that are not accompanied by accurate, complete, and validated documentation required by an ICCAT Bluefin Tuna Catch Documentation Program [Rec. 11-20],
- to prohibit domestic trade, imports, landings, placing in cages for farming, processing, exports, re-exports and the transhipment within their jurisdiction, of eastern and Mediterranean ABFT species caught by fishing vessels or traps whose flag State either does not have a quota, catch limit or allocation of fishing effort for that species, under the terms of ICCAT management and conservation measures, or when the flag State fishing possibilities are exhausted, or when the individual quotas of catching vessels,
- to prohibit domestic trade, imports, landings, processing, and exports from farms that do not comply with Recommendation 06-07.

5. Conclusions

ABFT is one of the most economic species of Mediterranean. After 1990s, the rapid development of ABFT farms has led to overfishing of this species. The Standing Committee on Research and Statistics (SCRS) has determined that ABFT stocks alerted and they recommended in the direction of decreasing quota as well should not fishing during its spawning season (ICCAT, 2007). However, this scientific recommendation was not adopted by ICCAT.

Restrictions on fishing for ABFT in the eastern Atlantic and Mediterranean have been implemented since 1998. ICCAT has determined the quota implementation for 2003, 2004, 2005 and 2006 as 32,000 t (ICCAT, 2002), for 2007 and 2008 as 29,500 t and 28,500 t respectively for the eastern Atlantic and Mediterranean stocks (ICCAT, 2006). In 2008, the ABFT stock assessment results indicated that the spawning stock biomass (SSB) has been declining rapidly in the last several years while fishing mortality (F) has been increasing rapidly, especially for large ABFT (i.e. ages 8+). The increase in mortality for large ABFT is consistent with a shift in targeting towards larger individuals destined for fattening/farming (ICCAT, 2008a).

Monaco has given a proposal directed to list ABFT in Appendix-1 of the “Convention on International Trade in Endangered Species (CITES)” in 2009 so as to forbid international trade. Countries such as USA, Norway, Switzerland, England and as well EU countries supported the initiative on some condition (Greenpeace, 2010).

SCRS has reported that ABFT has not yet seen the extinction of endangered species. Scientists have decided to ABFT had necessary criteria in order to listed in CITES Appendix-1 by estimating stocks of ABFT were at about 15% of pre-industrial fishing levels, furthermore they have asserted the commercial fishing had to be stopped until 2019 to not take part in the CITES list (ICCAT, 2009a). The matter of whether ABFT would be included in the endangered list was voted by countries during The Parties Conference (COP15) of CITES 15 in Doha/Qatar on 13-25 March 2010, and this offer was rejected by a majority of votes.

If the management of ABFT will be taken by the CITES than the credibility of ICCAT will be lost forever and this will cause unpredictable problems for many species and for the Regional Fisheries Management Organizations (FMOs) system in general (Di Natale, 2010).

After this event, ICCAT decided that fishing quota was 22,000 t in 2009 and 19,950 t in 2010 (ICCAT, 2008b) and 13,500 t in 2011 (ICCAT, 2009b). Moreover, the reduction of fishing capacity, existing of observers in vessels and farms, filling out of BCD forms in vessels during fishing and in farms during harvesting were recommended. ICCAT has started to monitor a variety of input (fishing effort and intensity) and output (ABFT catch documentation scheme, mandatory observer, etc.) fishery controls in the ABFT fisheries differently from fisheries management of other tuna species (Pope, 2002; Samuel, 2013).

Since 2008, there was a rapid decrease in the highest F on ages 10+ occurred from the mid-1990s to mid-2000s and SSB exhibited increase up to 300,000 t in the late 1950s and early 1970s were calculated in the 2012 stock assessment (Figure 5). This situation might be caused by reduction of fishing in the eastern Atlantic and Mediterranean according to the recent scientific recommendations and implementation of new monitoring and control measurement related to illegal, unreported and unregulated (IUU) fishing. But, the speed and the magnitude of SSB increase are higly uncertain. However, the available catch per unit effort (CPUE) indices are poor (ICCAT, 2012).

In stock assessment studies conducting by ICCAT, lack of fishing and farming available data are the major problems (ICCAT, 2012). When fishing is performed with purse seine in the Mediterranean is considered, CPUE in purse seine fishery and growth rates of caged ABFT are needed for stock assessment study.

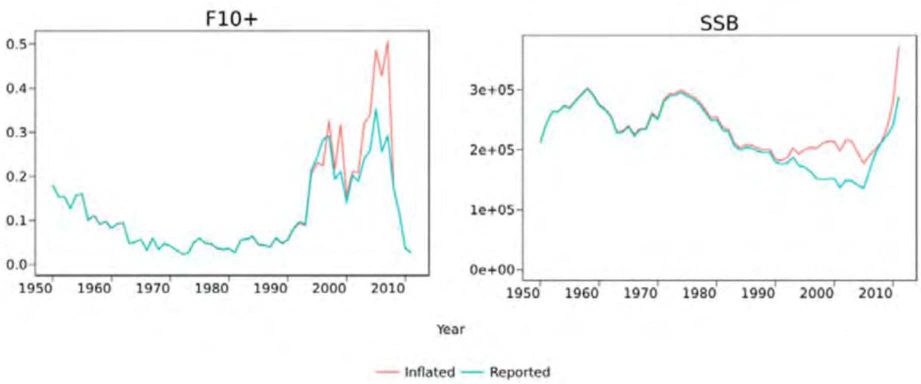

Figure 5. Fishing mortality at ages 10+ and SSB in the eastern Atlantic and Mediterranean according to last stock assessment (ICCAT, 2012)

Fishery-independent information is furthermore crucial to avoid biases due to management regulations in the models based on catch and CPUE. For this reason, fishery-independent studies (tagging program, aerial surveys, larval surveys, eco surveys etc.) which will show biomass trend and help for better calculation of fishing mortality rates are needed. Therefore, the Atlantic Wide Research Programme was started by ICCAT in 2010. ICCAT funding members are; European Union (80%), Algeria, Canada, China, Croatia, Japan, Korea, Libya, Morocco, Norway, Tunisia, Turkey, United States of America and Chinese Taipei. Objectives of this programme are; improving understanding of ABFT key biological and ecological processes, improving basic data collection including information from farms, observers, and vessel monitoring systems, improving assessment models and provision of scientific advice on stock status. Investigations which directed to monitoring must necessarily supported in order to confirm results of the last stock assessment with the fishery-independent data and address the concerns of civil society organizations

For sustainable use of stocks, studies related to production of ABFT under aquaculture condition aside from sea bream and seabass and reproduction in hatchery have importance. For this purpose, Turkish companies have begun to study in the Aegean Sea, it is expected to give positive results in the near future.

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MARINE AND COASTAL PROTECTED AREAS

OF TURKISH AEGEAN COASTS

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1. Introduction

The Aegean Sea is subdivision of the Mediterranean Sea between Turkey and Greece, and constitutes north-eastern part from which connects Sea of Marmara and then to Black Sea by Çanakkale and İstanbul Straits. It measures about 320 n. miles longitudinally, and narrowest distance is about 75 n. miles from Çeşme in Turkey to Euboea in Greece (Öztürk *et al.*, 2002). Due to its geomorphology as being an archipelago comprising over 3,000 island and islets, and hydrological characteristics it hosts significant marine biodiversity and habitats (*e.g.* Coll *et al.,* 2010; Şekercioğlu *et al.*, 2011; Çınar and Bilecenoğlu, 2014). Despite its natural value, UNEP –MAP (2012) in its State of the Mediterranean Marine and Coastal Environment report revealed the threats on the marine and coastal ecosystems that were no different for the Aegean Sea. These include; coastal development and sprawl, chemical contamination, eutrophication, marine litter, marine noise, invasive non-indigenous species, over exploitation of natural resources, damaged sea floor integrity and changed hydrographic conditions. In the light of these major findings and under the framework of integrated coastal zone management principles, marine and coastal protected areas can play an important management role to mitigate the effects of these threats at least in the marine and coastal biodiversity hot spots.

In parallel, the major outcome of the United Nations Conference on Sustainable Development (Rio+20) "The Future We Want" document underlined "the importance of the conservation and sustainable use of the oceans and seas and of their resources for sustainable development", and the article 177 dictated that the "importance of area-based conservation measures, including marine protected areas", and stressed that "decision X/2 of the tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD), that by 2020 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, [were] to be conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures" (Turkish Ministry of Development, 2012).

From the point of view of aforementioned threats to be mitigated and protection measures recommended by the CBD, Turkey's current status on MCPAs establishment and management in the Turkish Aegean coasts was briefed in this chapter. However, Gelibolu Yarımadası National Park was not taken into the list since the management objective is mainly on Çanakkale battle (Battle of Gallipoli) between 1915 and 1916.

2. National legislation and administration

Protected areas commenced to be founded and managed by the General Directorate of Forestry under Ministry Forestry mainly on the terrestrial hot spots in 1958 (Yücel and Babuş, 2005). With two exceptions[1], marine and coastal protected areas were established late 1980s. To date a total of 15 MCPAs comprising 10 Special Environmental Protection Areas (SEPAs), 3 National Parks (NPs), 1 Nature Strict Reserve (NSP), 1 Nature Park (NAP) were established under different protected area categories in Turkey (Güçlüsoy, 2015). This figure; however, do not include, total numbers of fisheries restricted areas, wetlands, wildlife reserves and natural SIT sites that are covering coastal marine area. To date, no MCPAs exist in the Sea of Marmara and Black Sea coasts, but 5 sites were proposed for the Black Sea (Öztürk *et al*. 2013).

Currently, two administrative bodies are responsible for the establishment and management MCPAs (TVKGM, 2014a). These are; General Directorate for Protection of Natural Assets (GDPNA)[2] under Ministry of Environment and Urbanization and General Directorate for Nature Conservation and National Parks (GDNCNP) under Ministry of Forestry and Water Affairs. The former DG manages the SEPAs and Natural SIT sites with the responsibility given by the decree law No. 644 and 648 in 2011, and the latter DG administers NPs, NPAs, NAPs and Nature Monuments (NM) with the duty inclined by the National Parks Law (No. 2873) in 1983. The GDPNA's administrative structure with respect to management of SEPAs on the Turkish Aegean coasts is given in Fig. 1. It is worth noting that no site specific units operate for management of these sites.

[1] *Dilek Yarımadası – Büyük Menderes National Park and Beydağları Sahil National Park were established in 1966 and 1972 respectively.*

2 *This DG was formerly entitled as Environmental Protection Agency for Special Areas, and it operated between 1988 and 2011 (TVKGM, 2014).*

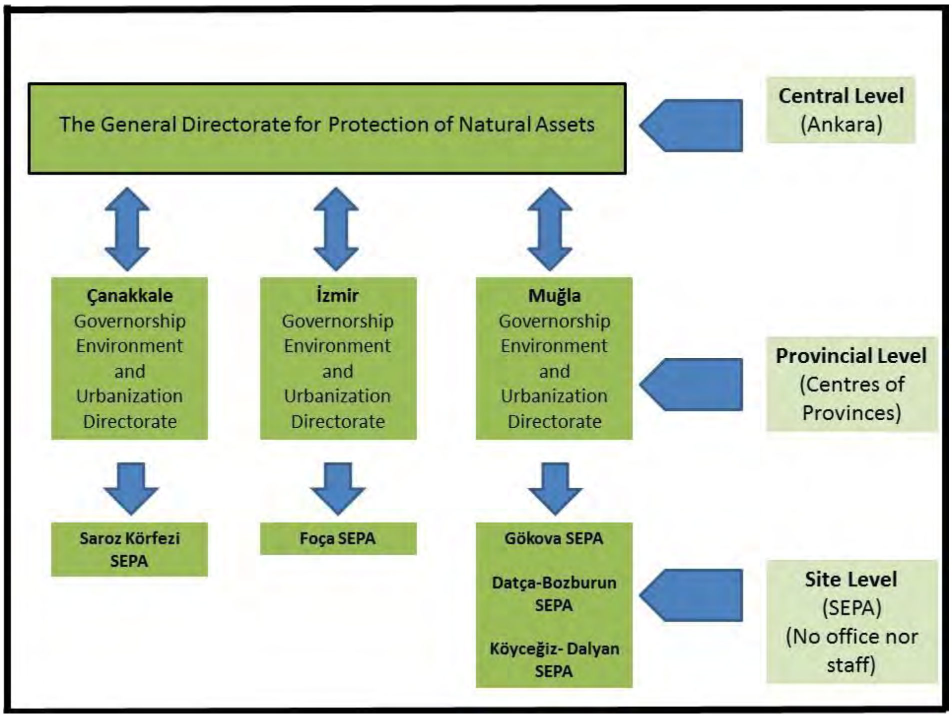

Figure 1. GDPNA's administrative structure for the management of each SEPA located on the Turkish Aegean Coasts.

The GDNCNP administrative structure differs from GDPNA since they do not involve governorships in respective coastal provinces. Rather, they have regional directorates in charge of more than one province. This is no different for the Turkish Aegean coasts from where two regional directorates are responsible (Fig. 2). However, on site management is in place with two different modalities for NPs and NAPs located in the Turkish Aegean coasts. Though, NPs in Dilek Yarımadası - Büyük Menderes Deltası and Marmaris NPs managed by NP Directorates that are directly linked with regional directorate (M. Uzuner, pers. comm., 21 September 2015), Ayvalık Adaları NAP runs by the park's chief office linked to provincial branch directorate and then to regional directorate. In the latter case, NAP management operations may take longer than anticipated (A. Tanrısever, pers. comm., 21 September 2015).

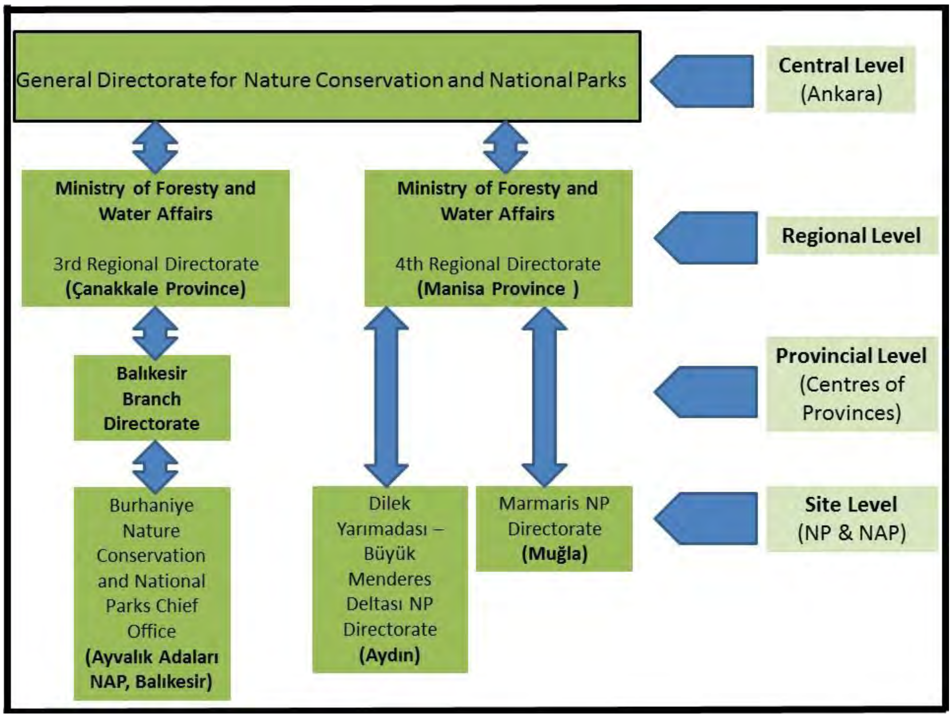

Figure 2. GDNCNP's administrative structure for the management of each NP and NAP located on the Turkish Aegean Coasts.

As a further note, all relevant conventions to which Turkey is a party and the national legislation including secondary ones regarding the protected areas were summarized in Yücel and Babuş (2005), Kaboğlu *et al*. (2005) and TVKGM (2014a).

3. MCPAs of Turkish Aegean

A total of 8 MCPAs comprising 5 SEPAs, 2 NPs and 1 NAP located on the Turkish Aegean coasts (see Fig. 3). Current knowledge on MCPAs on the Turkish Aegean Sea coasts – from north to south – was briefed below.

3.1 Saros Gulf SEPA

The Cabinet Decree, which declares Gulf of Saros-covering 53.834 ha marine area as SEPA, entered into force on 22 December 2010 (Official Gazette no: 27793). Gulf of Saros and its coastal area were declared as a SEPA due to its landscape, geomorphological, ecological, floristic biogenetic and touristic properties (EPASA, 2011). Some metrics of this SEPA are given in Table 1.

The marine species inventory project identified 78 marine plant, 34 sponge and 144 fish species (EPASA, 2011). In addition, a total of 57 crustacean taxa were also identified for Gulf of Saros in 2002 (Sezgin *et al*. 2007).

The water quality monitoring programme is in place since 2011. Further details on the baseline studies and management of Saros Gulf SEPA are given in Tab. 2.

Besides, The Coast of Gökçeada, which is the largest Island in Turkey, is very rich in terms of marine biodiversity and designated Potentially Marine Park since 1999. The rich habitat diversity is the main reason for the need to establish a marine park in region between Yıldızkoy to Çiftlik koy (Güreşen and Konya, 2014).

3.2 Ayvalık Adaları NAP

On the 21st April 1995 Ayvalık Adaları comprising 22 islands was declared as a "Nature Park" by the Decree of the Cabinet of Ministers official gazette number 22265 (TVKGM 2014b). Under Turkey's National Parks Law nature parks are defined as "natural areas of important vegetation and fauna characteristics that are suitable for human recreation within the integrity of the natural landscape" (Bann and Başak, 2013). Some descriptors of Ayvalık Adaları NAP are given in Tab. 1.

Inventory for macroscopic marine biodiversity along with physical parameters of surrounding water mass and status of the fishing activity studies were conducted in 2012 for this MCPA. As a result of this study, 671 species belonging to Polychaeta (198 species), Mollusca (169 species), Pisces (76 species), and Crustacea (69 species) were determined. In addition, a total of 37 phytobenthic species were identified. While three of them (*Posidonia oceanica*, *Cymodocea nodosa* and *Halophila stipulacea*) were flowering plants, the rest were algae. This study also revealed that coral reefs were the most important habitats in the Ayvalık Adaları NAP. Three species of fan corals (Gorgonacea, Anthozoa) were identified: *Eunicella cavolini, Eunicella singularis* and *Paramuricea clavata.* Moreover another coral species reported to be the colonizing stony coral *Cladocora caespitosa* (Yokeş and Demir, 2013).

Among 32 MCPAs and marine sites baring rocky reef ecosystems in the Mediterranean basin, Ayvalık Adaları NAP without any NFZ was assessed to be 18th in terms of fish biomass. Nevertheless, well enforced no take reserves (NFZs) were listed among first ranked MCPAs (Sala *et al*. 2012).

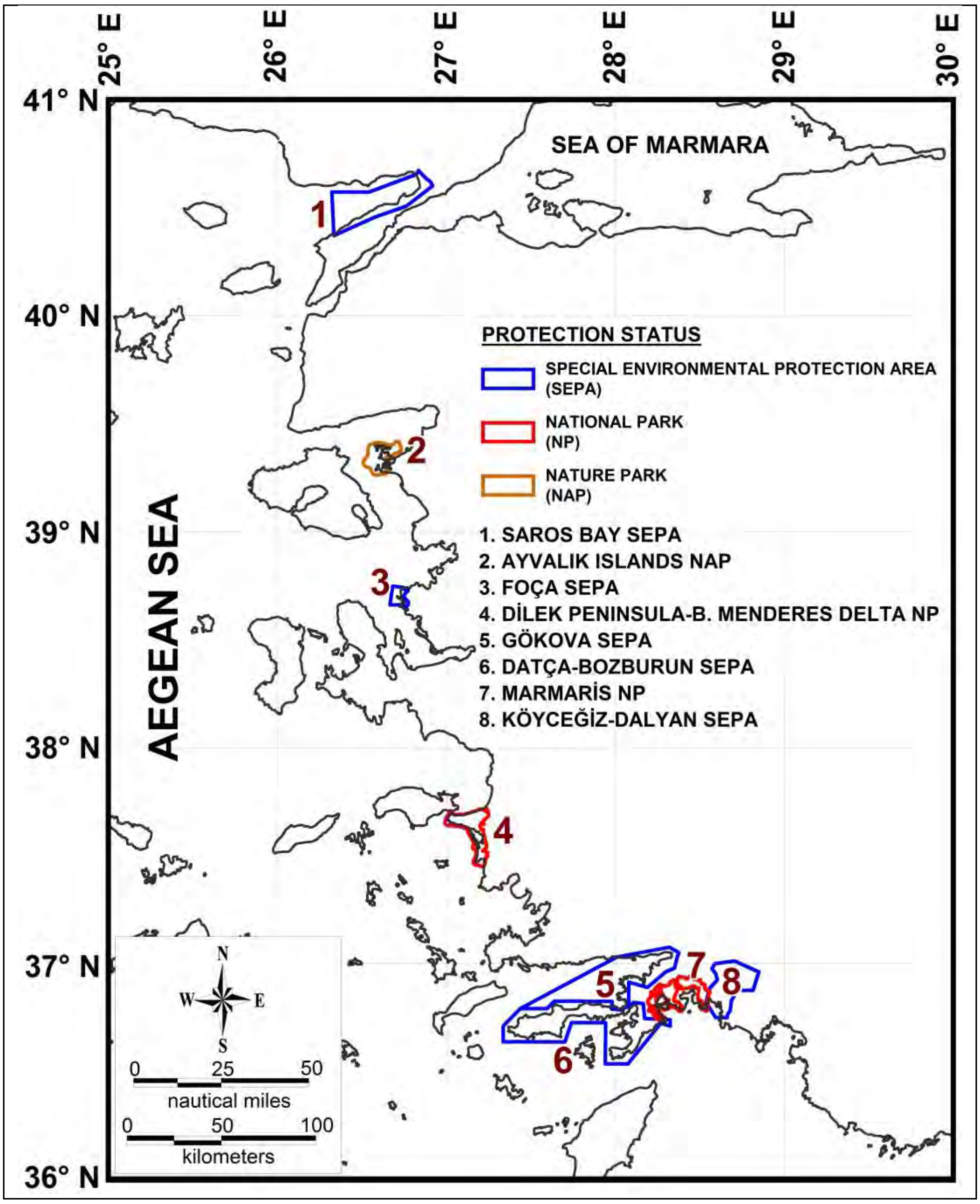

Figure 3. MCPAs of the Turkish Aegean coasts

Table 1. The foundation years, IUCN categories and some metrics of MCPAs on Turkish Aegean coasts

	Foundation Year	IUCN Category	Coastal length (km)[5,6,8]	Total Area Coverage (ha)[5,6,8]	Marine area coverage (ha)[5,6]	No of NFZs as core zone[9]
Saroz Körfezi SEPA	2010[1]	IV[5]	62	73,021	53,834	0
Ayvalık Adaları NAP	1995[2]	II[6]	110	17,950	14,200	0
Foça SEPA	1990[3]	IV[7]	28	7,144	5,178	0
Dilek Yarımadası - Büyük Menderes Deltası NP	1966[4]	II[7]	?	27,598	?	1
Gökova SEPA	1988[3]	IV[7]	193	109,778	82,023	6
Datça-Bozburun SEPA	1990[3]	IV[7]	417	144,389	73,663	4
Marmaris NP	1996[4]	II[8]	?	29,206	?	1
Köyceğiz-Dalyan SEPA	1988[3]	IV[7]	46	46,146	4,084	0
TOTAL			**856+**	**455,232**	**232,982+**	**12**

1) ÇŞB-TVKGM. (n.d) Saros Körfezi - Saros Körfez Özel Çevre Koruma Bölgesi. Retrieved September 22,2015, from http://www.csb.gov.tr/gm/tabiat/index.php?Sayfa=sayfa&Tur=webmenu&Id=203
2) OSB-DKMPGM (n.d.) Türkiye'nin Korunan Alanları. Retrieved September 22, 2015 from http://www.milliparklar.gov.tr/korunanalanlar/index.htm
3) TVKGM (2014b)
4) OSB-DKMPGM (n.d.) Türkiye'nin Milli Parkları. Retrieved September 22, 2015 from http://www.milliparklar.gov.tr/mp/dilekyarimadasi/index.htm
5) G. Ergün (pers. comm., 22 September 2015)
6) A.Tanrısever (pers. comm., 21 September 2015)
7) Kaboğlu *et al*. (2005)
8) M. Uzuner (pers. comm., 21 September 2015)
9) GTHB (2012)

Table 2. The baseline studies and management of MCPAs on Turkish Aegean coasts

	Field office	Baseline marine biodiversity study[1]	Baseline Socio-economic structure study[1,2]	Management Plan[1]	Business Plan[1]	Monitoring [1]	Surveillance[1,3]
Saroz Körfezi SEPA	0	1	1	0	0	1	*
Ayvalık Adaları NAP	1	1	0	0	0	0	**
Foça SEPA	0	1	1	1	0	1	*
Dilek Yarımadası - Büyük Menderes Deltası NP[4]	1	0	0	1	0	0	*
Gökova SEPA	0	1	1	1	0	1	***
Datça-Bozburun SEPA	0	1	1	0	0	1	*
Marmaris NP[4]	1	0	0	1	0	0	*
Köyceğiz-Dalyan SEPA	0	1	1	1"	0	1	*
TOTAL	**3/8**	**6**	**4**	**3**	**0**	**5**	

": for only terrestrial part

*: Surveillance in place under Coast Guard Command

**: Surveillance in place under Coast Guard Command and Food, Agriculture and Livestock Town Directorate

***: Surveillance in place under Coast Guard Command and site specific marine surveillance is also in place

1) G. Ergün (pers. comm., 15 October 2015)

2) Ü. Turan (pers. comm., 15 October 2015)

3) A. Tanrısever (pers. comm., 15 October 2015)

4) M. Uzuner (pers. comm, 16 October 2015)

Bann and Başak (2013a) assessed the Ayvalık Adaları NAP's marine and coastal ecosystem services by following the ecosystem service approach (ESA) based on the Millennium Ecosystem Assessment classification of ecosystem services into provisioning, regulating, cultural and supporting services. As a result, the total annual value of the ecosystem services was estimated to be around US$ 43 million per year. In addition, income generating activities both for respective MCPA administration and locals were also proposed for this MCPA (Başakand Yolak, 2013). Finally socio-economic overview, and some baseline and management information are provided by Keskin *et al*. (2011) and in Tab. 2 respectively.

3.3 Foça SEPA

Foça SEPA was established in 1990 (Official gazetted No. 20702, 21 Nov. 1990), and it was extended in 2007 (Official gazetted No. 26551, 13 June 1997) (TVKGM, 2014a,b). Foça was declared as a SEPA to protect natural and historical assets of the region (EPASA, 2011). Some metrics of this SEPA are given in Table 1.

One of the schools of thought in ancient era was "Phocaea" town received its name after the settlers "saw a seal coming to dry land" (Johnson and Lavigne, 1999). After 2.5 millennia this is no different among Turkish residents, and many believe that Foça, meaning seal, is the main habitat for the Mediterranean monk seal (*Monachus monachus*). This was why main species conservation actions commenced in Foça right after the establishment of the National Monk Seal Committee in 1991 (Güçlüsoy and Savaş, 2003). Last published research by Kıraç and Güçlüsoy (2008) estimated that there were only 3 individuals of this critically endangered species live between 2004 and 2007. However, a new study should be required to update current status of this species. Nevertheless, beside a single species management in the area, GDPNA made efforts to prepare the first management plan (EPASA, 2011; TVKGM, 2011). The plan is currently under revision for the second term.

Posidonia oceanica coverage was calculated as 6.7 km^2 for the Foça SEPA, and their carbon sequestration value was calculated at 400,000 USD (Bann and Başak 2011a). Furthermore, two monitoring stations for Posidonia were placed in 2008, and the baseline conditions of the Posidonia meadows were found to be weak in terms of depth limits, density - number of shoots/m^2 - and coverage (%) (Akçalı *et al*., 2008).

The baseline biodiversity inventory studies both in marine (DEÜ-DBTE, 2008) and terrestrial (EKAD, 2013) terrains were completed (Table 2). As a result 168 marine and 548 terrestrial (291 plant- 257 animal) organisms were identified. Bann and Başak (2013b) found out the total annual value of Foça SEPA's marine and coastal ecosystem was estimated to be around US$ 37 million per year. The first socio-economic study was conducted in 2008 (Bann and Başak, 2011a). Both marine biodiversity and socio-economic research results were contributed for the first management plan and its associated interim business plan[3] preparation. Though these plans exit for this SEPA, no operational management unit is in place. Therefore, the water quality and monk seal monitoring programmes outsourced by the GDPNA.

3.4 Dilek Yarımadası - Büyük Menderes Deltası NP

Dilek Yarımadası was founded as a NP in 1966, and it was extended to circumscribe Büyük Menderes Delta in 1994 (Kılıçaslan *et al.*, 2011). As aforementioned due to its administration in those years, the area was established because of its forest ecosystem and extended to engulf the important wetland. This NP has a numerous variety of plants belonging to 95 families, and 42 reptiles, 256 bird - among which 70 breeding - and 28 mammal species (Kılıçaslan *et al.*, 2011). However, to date very little was done in the marine area of this NP (*e.g.* monk seal survey in 1988 by ODTÜ-SAT-AFAG). This NP mainly managed for daily recreational use such as swimming and bathing, picnicking facilities and tracking routes (Kılıçaslan *et al.*, 2011). Some descriptors, baseline figures and management activities of this NP are given in Tables 1 and 2.

3.5 Gökova SEPA

Gökova SEPA was founded in 1990 (Official gazetted No. 20702, 21 Nov. 1990), and it was extended to its current borders in 2010 (Official gazetted No. 27793, 22 December 2010) (EPASA, 2011; TVKGM, 2014b). Gökova was declared as a SEPA to protect natural (*e.g.* Kadın and Akçapınar streams, and sweet gum forest *Liquidambar orientalis*) and historical assets of the region (EPASA, 2011). Some metrics of this SEPA are given in Table 1.

Gökova MCPA is one of the most studied MCPAs in Turkey. Eleven marine and coastal projects on such as marine species inventory, ICM, fisheries, and management plan preparation were carried out between 2000 and 2012 (Kıraç *et al.*, 2012). Prior to extension of this SEPA, in their comprehensive study in the zone between supralittoral and 55 m depth Okuş *et al.* (2006) inventoried 723 macroscopic species comprising 79 flora and 644 fauna taxa. Among these species, 34 of them were under protection by Bern and/or Barcelona Conventions and national Fisheries Circular. In addition, 101 phytoplankton, 110 zooplankton and 26 alien species were identified. Boncuk cove of Gökova SEPA is also known one of the three nursery sites in the Mediterranean Sea and species area use is monitored irregularly (*e.g.* Bilecenoğlu, 2008).

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[3] *This report could not be concluded due to lack of local administrative structure (local management unit).*

As it was carried for Ayvalık NAP, Sala *et al*. (2012) also assessed marine sites of Gökova SEPA baring rocky reef ecosystems, and reported this MCPA is the worst in terms of fish (4 g /m^2) biomass. However, after the establishment of 6 NFZs and their effective protection by ranger systems, fish biomass values reached to 8 g/m^2 and 70 g /m^2 in 2014 in and out of NFZs respectively (Z. Kızılkaya pers. comm., 30 October 2015).

Bann and Başak (2011b) also assessed the Gökova SEPA's marine and coastal ecosystem services and the total annual value of these services was estimated to be around US$ 31.2 million per year. The water quality monitoring programme continues since 2006. Additional information on the baseline studies and management of this SEPA are given in Table 2.

3.6 Datça-Bozburun SEPA

The Cabinet Decree, which declares Datça and Bozburun as SEPA, entered into force on 2 March 1990 (Official Gazette no: 20449) (TVKGM 2014b). Some descriptors of this SEPA are given in Table 1.

Okuş *et al*. (2007) inventoried 807 marine species between 2002 and 2004. The most diverse phylum was Mollusca (n=187), followed by fishes (n=184) and algae (n=139). Among these species, 35 of them reported to be protected by Bern and Barcelona Convention's lists and national legislation such as Fisheries Law/Circular.

The socio-economic analysis of marine capture fisheries conducted at 10 fishing ports – comprising 3 fisheries cooperatives – for this SEPA revealed significant findings between 2010 and 2011. Fishermen reported to receive 33% of their income from fishery and the rest from both tourism and agriculture. 41 % of the fishermen only depended on fishing. Economic analysis results showed that only 10% of the fishermen in the entire Datça-Bozburun SEPA could reach net profits and the rest had made loss. The main problems reported were: illegal fishing activities, lack of fishing ports and facilities, lack of financial sources and puffer fish (*Lagocephalus sceleratus*) causing considerable damage to fishermen's gear in this SEPA (Ünal, 2011).

Bann and Başak (2013b) estimated the total annual value of Datça-Bozburun SEPA's marine and coastal ecosystem to be around US$ 38.2 million per year. The water quality monitoring programme continues since 2006. More information on the baseline studies and management of this SEPA are presented in Table 2.

3.7 Marmaris NP

Marmaris NP was established in 1996. As also described for Dilek Yarımadası – Büyük Menderes Deltası NP, to date no programmatic marine studies were conducted in this NP, main interest was on forest assets of the area (*e.g.* Kaynaş and Gürkan, 2005). Some metrics, baseline figures and management activities of this NP are given in Tab. 1 and 2.

3.8 Köyceğiz - Dalyan SEPA

Köyceğiz - Dalyan SEPA determined and founded by Decree of Cabinet of Ministers in 1988 (No. 88/13019, 12 June 1988) and it borders had changed twice to reach its current limits in 1990 (Decree of Cabinet of Ministers No. 90/77, 18 January 1990) and 2000 (Official gazetted No. 24055, 21 May 2000) respectively (EPASA, 2011; TVKGM, 2014b). Gökova was declared as a SEPA to protect natural and historical assets of the region (EPASA, 2011). It is one of good exemplary site where it was represented by lake, lagoon, marine and forest ecosystems. Some metrics of this SEPA are given in Table 1.

Dalyan beach – 4.7 km – is one of the most significant reproductive sites for loggerhead sea turtles (*Caretta caretta*). The beach also used by the Nile soft shell turtles *Trionyx tringuis* for nesting. Dalyan beach contributed about 12 % of overall nesting efforts of *Caretta caretta* in Turkey. Except for 1995, this beach monitored during nesting period since it was established as SEPA in 1988. Ekincik beach the northern most nesting site for *Caretta caretta* is also within the borders of this SEPA (Türkozan and Kaska, 2010).

In marine and coastal biodiversity assessment study 160 macro benthic and nektonic species of fauna, and 122 planktonic and nektonic species of flora were identified. Among these species, 17 of them were red list species and 10 of them were alien species (Bizsel *et al*. 2010).

Bann and Başak (2013c) estimated the total annual value of Köyceğiz-Dalyan SEPA's marine and coastal ecosystem to be around US$ 51.2 million per year. The water quality monitoring programme continues since 2006. More information on the baseline studies and management of this SEPA are presented in Table 2.

Conclusion

It is worth noting that all the protected areas overviewed above had both marine and terrestrial components. To date, no marine protected area only confined to marine space was established in the Turkish Aegean. In order to have a programmatic approach for better management of the system of MCPAs in Turkish coasts, drafted National Strategy of Marine and Coastal Protected Areas of Turkey (TVKGM 2014a) should be approved by the Ministry of Environment and Urbanization. In line with this Strategy, the marine area coverage of MCPAs should be increased from 4% to reach CBD's 10% target by 2020. As a recent initiative, Karaburun Peninsula and it surrounding marine area was assessed to be one of the new SEPA sites by the TVKGM in 2013 (TVKGM, 2013). However, this decision is still pending at the board of Ministers. In addition, proposed high sea marine protected areas (*e.g.* Öztürk, 2009) and trans-boundary protected areas for endangered species such as *M. monachus* (*e.g.* Berkes, 1978) in this sea need further attention of the riparian countries' officials. Finally, for the better management of SEPAs, management units should be operational to implement management plans confined to each SEPA. Foça, Gökova and Köyceğiz-Dalyan SEPAs can be good candidates to be upgraded as SPAMIs (Specially Protected Areas of Mediterranean Importance) under Barcelona Convention.

Acknowledgements

I would like to thank Güner Ergün, Dilek Tezel, Ümit Turan, Mehmet Uzuner, Atasay Tanrısever, Yıldıray Lise and Bayram Öztürk for their data provision and/or comments, and also Gökhan Kaboğlu for his map preparation.

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A GLANCE AT THE AEGEAN SEA THROUGH THE EYES OF INDICATORS

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1. Introduction

Overexploitation of marine fisheries resources has been a growing concern over the last few decades as a response to growing size of the fishing fleets, developing technology in the fishing, globalization of fish food market and rising societal and economic needs of the increasing global human population (FAO, 2014). Management of fisheries under ecologically and socio-economically sustainable policies has been raised as a challenging issue and aimed by the Ecosystem Approach to Fisheries (EAF) and the EU fisheries legislation, Marine Strategy Framework Directive (MSFD) (Borja *et al.,* 2013). From these aspects, use of indicators can result in a real, wide-reaching evaluation and provide guidance for EAF implementation and Good Environmental Status (GES) achievement by enabling the understanding of the important processes occurring in the fisheries and their supporting ecosystems, determination and monitoring the achievability of future targets (Jennings, 2005; Shin *et al.,* 2010).

Fisheries has been one of the rapidly growing sectors in Turkey occasionally financed by state subsidies for the development of its technological infrastructure in order to increase its production weight and value, and provide job opportunities (Ünal and Göncüoğlu, 2010). As a result, long term alterations occurred in the fishing pressures exerted on the surrounding marine ecosystems that had potentially resulted in changes in the regional fisheries and marine ecosystem structures. Turkey's Aegean Sea fisheries have been historically important for the local people considering the Turkey's 2,805 km coastline on the Aegean Sea. In 2014, 33.5 tons of fish and other sea products (59.4% consisted of anchovy and sardine) was landed by 6,488 fishers from the Aegean Sea. Turkish Aegean Sea fishing fleet mainly consists of small scale fisheries where 4,228 of total 4,372 vessels were below 12 m, 4,328 of them weighted less than 50 GT and 3,397 of them were powered with less than 50 HP engine in 2014 (TurkStat, 2015).

This chapter basically attempts to understand the direction and magnitude of the historical changes in the Turkey's Aegean Sea fisheries and the corresponding response of its supporting ecosystem through the eyes of indicators. Learning from the indicator-based assessments, it was aimed to inform the future decision making processes for a successful implementation of EAF and achievement of the Good Environmental Status

(GES) in the region in order to ensure sustainable utilization of the Aegean Sea ecosystem for the needs of today's and future generations.

2. Material and Methods

Data source: In this study, the 1970-2014 Aegean Sea fisheries landings and fleet data were directly taken from the DEKOYON Project database (dekoyon.ims.metu.edu.tr) which was constructed by the extraction of the data from the annual Fishery Statistics booklets published by the Turkish Statistical Institute. The official fisheries statistics were collected applying biannual surveys during January and May of each year by the Turkish Statistical Institute.

Indicators: A set of fisheries and ecological indicators were selected depending upon the availability of data time-series.

Fisheries indicators; The Aegean Sea fisheries landings, number of vessels and fishers in the fleet, fleet's fishing effort in total engine power, Catch per Unit Effort (CPUE) and Catch per Fisher (CPF) were used as fisheries indicators in this study.

Fishing effort as the total engine power of the fleet was estimated by giving average values to each HP class (9 HP for 1-9 HP class, 15 HP for 10-19 HP class, 45 HP for 20-49 HP class, 75 HP for 50-99 HP class, 200 HP for 100HP+ class) and number of fishers in the fleet was calculated by giving average values to each employment class (3 for 1-4 fisher class, 7 for 5-7 fisher class, 15 for 10-19 fisher class, 25 for 20-29 fisher class and 45 for 30 fisher+ class).

CPUE was found as the ratio of landings to the estimated fishing effort whereas CPF was the ratio of landings to the estimated total number of fishers in the fleet so as to track the efficiency of the Aegean Sea fisheries.

Ecological indicators; Depending upon the data availability and Aegean Sea characteristics, a set of landings-based ecological indicators were selected. Their calculation and interpretation with respect to fisheries and warming of the water temperature were summarized in Table 1.

Statistical analyses: Nonparametric Mann-Kendall tests were used to test for significant long-term trends in the indicators and Spearman's rank correlation statistics were applied to detect the relationships between the indicators.

Table 1. Selected ecological indicators, their calculation and interpretation. Trophic level, mean length and intrinsic vulnerability for each fish group were assigned according to FishBase (www.fishbase.org) and mean temperature preference of each fish group was defined according to Cheung *et al.* (2013).

Indicator	Calculation/Comment	Interpretation
Mean Trophic Level of fish in the landings (mTL)	The weighted average trophic level of all fish species in the landings. Representing the trophic position of the whole catch, this indicator is used to assess the 'fishing down the food web' effect of the fisheries on the marine ecosystem as the fisheries tends to target species at higher TLs first (Pauly *et al.,* 1998).	Decreases in response to overfishing
Marine Trophic Index of the landings (MTI)	The weighted average trophic level of all fish species in the landings excluding the fish of TLs below 3.25. Used to assess the changes in the mean trophic level of species at intermediate and upper trophic levels excluding the effect of eutrophication induced change in small pelagic fish (Pauly and Watson, 2005).	Decreases in response to overfishing
Proportion of small pelagic fish in the landed fish weight (SmallP)	The ratio of small pelagic fish to all landed fish. Used as supplementary indicator for mTL and MTI to detect the 'fishing down the food web' effect of the fisheries on the marine ecosystem.	Increases in response to overfishing
Mean length of fish in the landings (mLength)	The weighted average mean length of all fish species in the landings. Used to track fishing effects on an ecosystem as the fishery removes larger fish first from the ecosystem (Shin *et al.,* 2005).	Decreases in response to overfishing
Intrinsic Vulnerability Index of the landings (IVI)	The weighted average intrinsic vulnerability of all fish species in the landings. Used to track the overexploitation status of the more vulnerable species under fishing pressure (Cheung *et al.,* 2005).	Decreases in response to overfishing
Mean Temperature preference of the landed fish (mTemp)	The weighted average inferred temperature preference of all fish species in the landings. Used to detect if there is a potential signature of warming in the ecosystem (Cheung *et al.,* 2013).	Increases as a response to increasing sea temperature

3. Results and Discussions

The results of the Man-Kendall trend test and Spearman Rank Correlation analyses of the indicators were given in Tables 2 and 3. According to the results, landings, number of vessels and fishers in the fleet and fishing effort increased significantly and were found to be significantly correlated among each other. Landings reached its maximum level before 2000s, however, the growth of the vessel and fisher numbers and fishing power of the fleet continued up to their maximum values in the mid-2000s (Figure 1). For this reason, fisheries efficiency was higher during the 1980s and 1990s with higher CPUE and CPF values and rapidly decreased towards the late 1990s. 2000-2005 was the period when the fishing pressures continued to grow despite relatively low fishing efficiency. During the last decade (2005-2014), significant decreases were observed in the landings (46%), number of vessels (26%) and fishers (25%), fishing effort (21%) along with a very low fishing efficiency (Table 2).

Regarding the ecological indicators, significant positive trends in SmallP (from 17% to 78%) and MTI (from 3.92 to 3.95), and negative trends in mLength (from 38 cm to 24 cm) and IVI (from 45 to 32) were detected (Table 2). The significant increase of SmallP and decrease of mLength and IVI despite the insignificant trend in mTL time series could be considered as the occurrence of a "fishing down the food web" phenomenon (Pauly *et al.,* 1998) in the Aegean Sea ecosystem. Insignificancy of the trend in the mTL might have been caused by a possible shift in the dominance of different small pelagic fishes that have higher TL level. No significant signature of the global warning was detected in the mTemp time series. However, strong significant correlations were found between SmallP, mLenght, IVI and mTemp and weak significant correlation was observed between mTL and MTI (Table 3). The highly-correlated mLength, IVI and mTemp displayed similar decreasing trends during the 1970s, increasing trends during the 1980s and 1990s, and they rapidly decreased after 2000s when the fishing pressures continued to increase despite the very low fishing efficiency. Meanwhile, SmallP displayed a parallel but reverse trend compared to these three indicators as it was found to be negatively correlated. According to the Man-Kendall analysis, trends in the time series of the SmallP, mTL and mLength indicators were found to be significant over the last decades.

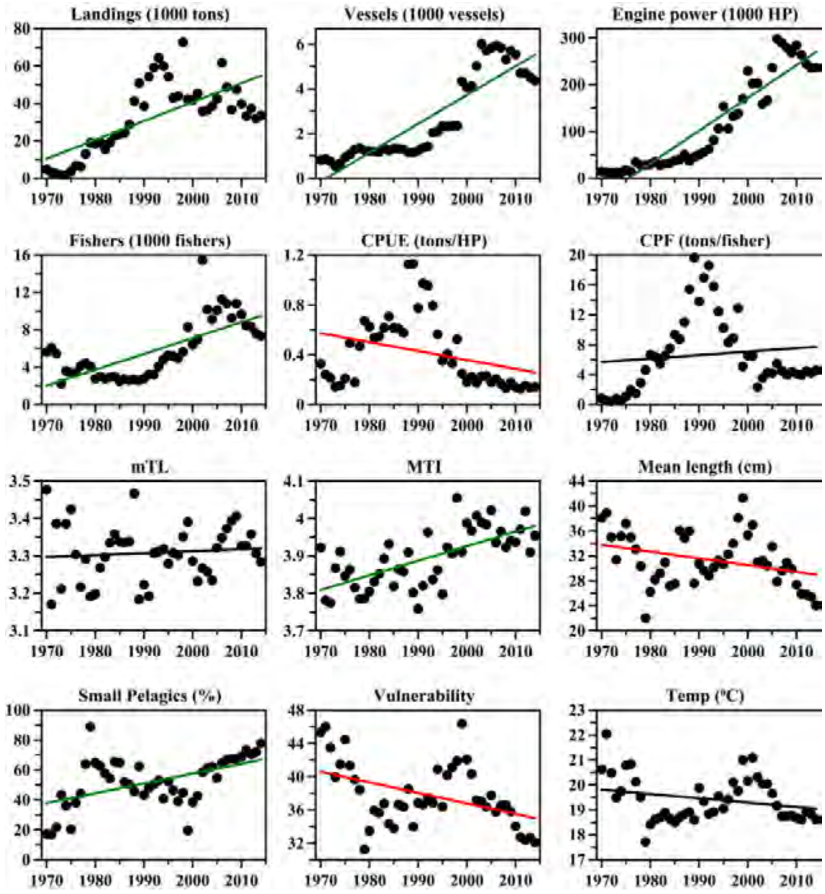

Figure 1. Time series of the selected indicators. Solid lines display the linear trends in the time series (black, green and red colours refer to insignificant, positive significant and negative significant trends respectively according to the Mann-Kendall trend test results)

In summary, the indicator trends and interrelations observed between the indicators in this study could be communicated as follows; i) Aegean Sea fisheries fleet has developed an over-fishing capacity, too many fishers are exploiting the constrained amount of stocks with excessive number of vessels that have excessive engine power with very low efficiency, especially after the 2000s, ii) this fishing over-capacity eradicated the long sized, vulnerable fish species from the ecosystem and the ecosystem became dominated by small pelagic fish significantly since the 2000s, iii) even though the numbers of fishers, vessels and fishing effort of the fleet have been decreasing within the last decade, ecological indicators continued to give warning signals for a possible more severe deterioration in the Aegean Sea ecosystem.

Table 2. Summary information of the selected indicators from 1970-2014 and Mann-Kendall trend test results.

Indicators	Summary information				Mann-Kendall trend analayses			
	1970	2014	Mean	Std. deviation	1970-2014		2005-2014	
					Test Z	Signific.	Test Z	Signific.
Landings (ktons)	4,63	33,54	32,57	19,02	4,65	***	-2,33	*
# of Vessels (x1000)	0,82	4,37	2,69	1,91	7,16	***	-3,14	**
# of Fishers (x1000)	14,15	236,23	5,76	3,14	4,41	***	-3,04	**
Fishing effort (HP)	5,61	7,34	115,46	99,04	8,21	***	-2,15	*
CPUE (tons/HP)	0,33	0,14	0,42	0,28	-3,18	**	-1,61	
CPF (tons/fisher)	0,83	4,57	6,70	5,05	1,07		-0,18	
SmallP (%)	17,17	77,81	52,81	16,83	3,77	***	3,40	***
mTL	3,48	3,28	3,31	0,07	0,89		-0,89	
MTI	3,92	3,95	3,89	0,08	4,51	***	-0,18	
mLength (cm)	38,07	24,04	31,35	4,30	-2,55	*	-3,04	**
IVI	45,33	32,09	37,79	3,82	-2,91	**	-3,04	**
mTemp (^{0}C)	20,62	18,61	19,43	0,90	-1,09		-1,43	

Table 3. Spearman correlation analyses results of the selected indicators. Values in bold are different from 0 with a significance level alpha=0.05

Variables	Land.	Vessel #	Fisher #	Fishing eff.	CPUE	CPF	SmallP	mTL	MTI	m Length	IVI	m Temp
Land.	**1**	**0.63**	**0.70**	**0.32**	0.17	**0.68**	0.13	0.03	**0.38**	-0.11	-0.10	-0.07
Vessel #	**0.63**	**1**	**0.94**	**0.79**	**-0.44**	0.07	**0.48**	0.10	**0.69**	-0.27	**-0.30**	-0.08
Fisher #	**0.70**	**0.94**	**1**	**0.72**	**-0.45**	0.18	**0.48**	0.14	**0.67**	**-0.30**	**-0.36**	-0.17
Fishing eff.	**0.32**	**0.79**	**0.72**	**1**	**-0.70**	**-0.41**	0.23	0.18	**0.64**	-0.03	0.01	0.26
CPUE	0.17	**-0.44**	**-0.45**	**-0.70**	**1**	**0.72**	-0.17	-0.20	**-0.49**	0.01	0.00	-0.17
CPF	**0.68**	0.07	0.18	**-0.41**	**0.72**	**1**	0.07	-0.11	-0.10	-0.17	-0.23	**-0.36**
SmallP	0.13	**0.48**	**0.48**	0.23	-0.17	0.07	**1**	-0.08	0.19	**-0.88**	**-0.92**	**-0.80**
mTL	0.03	0.10	0.14	0.18	-0.20	-0.11	-0.08	**1**	**0.31**	0.22	0.16	0.00
MTI	**0.38**	**0.69**	**0.67**	**0.64**	**-0.49**	-0.10	0.19	**0.31**	**1**	0.01	-0.02	0.08
mLength	-0.11	-0.27	**-0.30**	-0.03	0.01	-0.17	**-0.88**	0.22	0.01	**1**	**0.91**	**0.79**
IVI	-0.10	**-0.30**	**-0.36**	0.01	0.00	-0.23	**-0.92**	0.16	-0.02	**0.91**	**1**	**0.86**
mTemp	-0.07	-0.08	-0.17	0.26	-0.17	**-0.36**	**-0.80**	0.00	0.08	**0.79**	**0.86**	**1**

These interpretations presented here should be considered tentatively due to possible biases and uncertainties in the official data utilised in the analyses and the probability that they may not fully represent the real situation occurred over the analysis time frame. However, in the absence of more reliable data sources, it can still be considered useful to understand the long term trends in the fisheries and corresponding changes in the ecosystem. This study indicated the urgency for further decrease in the fishing effort and number of fishers in the Aegean Sea fisheries, all of which seem to be consistently detrimental for ecosystem as well as fishing efficiency. At this point, the scope of the recently implemented buy-back program could be extended and alternative employment opportunities may be provided to fishers. Detailed and extensive stock assessments are required in relation to stock status and fishing mortality reference points that will eventually lead to conservation policy through management measures. The adequacy of the future management applications could be observed by building upon the time-series of indicators provided in this study.

Acknowledgements

This study was carried out with the support of TUBITAK 113Y040 DEKOYON and METU-CARES / Center for Marine Ecosystems and Climate Research Project (DEKOSIM) projects.

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MARINE STRATEGY FRAMEWORK DIRECTIVE AND THE AEGEAN SEA

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1.Introduction

1. Marine Strategy Framework Directive (MSFD)of EU (2008/56/EC) [4]. The Marine Strategy Framework Directive (MSFD) came into force in 2008 after several years of preparation and was adopted by Member States in 2010. The MSFD requires each Member State to develop a marine strategy for its marine waters. The MSFD aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and protect more effectively the marine environment across Europe. To help Member States to implement the Marine Directive, the Commission also produced in 2010 a set of detailed criteria and indicators. These criterias and indicators will give a route for the EU candidate countries. Currently, the European fisheries sector is being regulated by a variety of regulations. To better understand the point of view key European policies which directly influence the management of the marine environment can be listed as follows: The Common Fisheries Policy (CFP)[5], Blue Growth[6], EU Water Framework Directive (WFD)[7], Integrated Maritime Policy (IMP)[8], Marine Strategy Framework Directive (MSFD)[9], Limassol Declaration[10], EU Biodiversity Strategy and Natura 2000[11], Marine Spatial Planning (MSP)[12], EU Integrated Coastal Zone Management[13], Mediterranean Action Plan (MAP)[14].

2. What is the aim of the Marine Directive and how does it work?

The Marine Directive aims to achieve Good Environmental Status (GES)[15] of the EU's marine waters by 2020 and to protect the resource base upon which marine-related

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4 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF
5 http://ec.europa.eu/fisheries/cfp/index_en.htm
6 http://ec.europa.eu/maritimeaffairs/policy/blue_growth/
7 http://ec.europa.eu/environment/water/water-framework/index_en.html
8 http://ec.europa.eu/maritimeaffairs/documentation/publications/documents/imp-progress-report_en.pdf
9 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF
10 http://ec.europa.eu/maritimeaffairs/policy/documents/limassol_en.pdf
11 http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm
12 http://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning/index_en.htm
13 http://ec.europa.eu/environment/iczm/home.htm
14 http://ec.europa.eu/enlargement/archives/seerecon/infrastructure/sectors/environment/ri/mep.htm
15 http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm

economic and social activities depend. In previous sections of this book many researchers mentioned the 11 topics of GES (Biodiversity, Non-indigenous species, Commercial fish and shellfish, Food webs, Eutrophication, The sea floor integrity, Hydrographical conditions, Contaminants, Contaminants in seafood, Marine litter, Energy including underwater noise). Marine directive is the first EU legislative instrument related to the protection of marine biodiversity, as it contains the explicit regulatory objective that "biodiversity is maintained by 2020", as the cornerstone for achieving GES. The Directive enshrines in a legislative framework the ecosystem approach to the management of human activities having an impact on the marine environment, integrating the concepts of environmental protection and sustainable use. In order to achieve its goal, the Directive establishes European marine regions and sub-regions on the basis of geographical and environmental criteria. The Directive lists four European marine regions – the Baltic Sea, the North-east Atlantic Ocean, the Mediterranean Sea and the Black Sea – located within the geographical boundaries of the existing Regional Sea Conventions. Cooperation between the Member States of one marine region and with neighbouring countries which share the same marine waters, is already taking place through these Regional Sea Conventions. In order to achieve GES by 2020, each Member State is required to develop a strategy for its marine waters (or Marine Strategy). In addition, because the Directive follows an adaptive management approach, the Marine Strategies must be kept up-to-date and reviewed every 6 years. Also candidate countries have to be integrated to these directives. For the scientific support and updates Joint Research Centre (JRC), The Marine Strategy Framework Directive (MSFD) Competence Centre (MCC)[16] was established, to share harmonised marine policy and science information, and to provide the MSFD Common Implementation Strategy with up-to-date scientific knowledge

3. What does a Marine Strategy include?

- The initial assessment of the current environmental status of national marine waters and the environmental impact and socio-economic analysis of human activities in these waters (by 15 July 2012)
- The determination of what GES means for national marine waters (by 15 July 2012)
- The establishment of environmental targets and associated indicators to achieve GES by 2020 (by 15 July 2012)
- The establishment of a monitoring programme for the ongoing assessment and the regular update of targets (by 15 July 2014)
- The development of a programme of measures designed to achieve or maintain GES by 2020 (by 2015)
- The review and preparation of the second cycle (2018 – 2021)

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[16] http://mcc.jrc.ec.europa.eu/

Marine strategies are being implemented to protect and conserve the marine environment, prevent its deterioration, and, where practicable, restore marine ecosystems in areas where they have been adversely affected.

4. History of MSFD in Turkey

The experience of the implementation of the first phase of the MSFD is not only a guide for the candidate countries (CCs) like Turkey, but also an improvement opportunity for reviewing and revising ongoing assessment tools applied to the marine environment and relevant services to society. Turkey as a non-EU Member State is not obliged to implement the MFSD, however as a CC for EU membership, they are in the process of bringing their national legislation in line with European policy. The formal accession negotiations (which started on October 3rd, 2005 for Turkey) requires candidate countries to bring national legislation into compliance with 35 chapters of EU law, known as the ‘acquis’, before they are eligible to become a full member. Each candidate has to open the negotiation chapters, harmonize their legislation and its implementation to *acquis* with the help of EU financial assistance and apply for the closing of the related chapter(s). Negotiation chapters are provisionally closed if the candidate country's adoption of the *acquis* and its degree of implementation are seen as sufficient.

An analytical examination of EU legislation (the so-called screening process) is undertaken by CCs as they are required to include conformity of national legislation to EC’s environmental directives. This is the case of the MSFD and attaining GES for Turkish coastal waters. Within the scope of the EU membership process, the Chapter on Environment, which includes the MSFD, was opened to accession negotiations at the Intergovernmental Conference, held in Brussels on 21 December 2009. Accordingly, the Ministry of Environment and Urbanization (MoEU) had a comprehensive research project designed and carried out by Marmara Research Center of Turkish Science and Technology Council (TUBITAK-MRC)[17] between 2011 and 2013. The ‘Marine and Coastal Waters Quality Determination and Classification’ project (DeKoS), which was a baseline project for MSFD requirements in Turkey, was specifically designed to target the determination and classification of marine water status relevant to both WFD and MSFD. But up to 2012 what was the situation and legislations in Turkey.

There is comprehensive set of legislation for the gradual well-coordinated transposition, implementation and enforcement of the MSFD, assuring marine safety and preventing marine pollution, which includes: the Environmental Law revised in 2006, the Law Pertaining to Principles of Emergency Response and Compensation for Damages in pollution of Marine Environment by Oil and Other Harmful Substances

[17] http://mam.tubitak.gov.tr/en

(OSRL), the Coastal Law (1990), the Law on the Bosporus 1983, and the EU Integrated Environmental Approximation Strategy (UÇES) 2007-2023[18][19].

Turkey has a large legal framework providing regional involvement of MSFD related tasks which includes:

- Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention), 1976, ratified by Turkey in 1995.

The Barcelona Conventions Protocols on (i) Dumping, (ii) Prevention and Emergency, (iii) Land-based Sources and Activities, (iv) Specially Protected Areas and Biological Diversity, (v) Hazardous Wastes, and (vi) Offshore Protocol have been also ratified.
Ongoing studies are organized for ratifying the Protocol on Integrated Coastal Zone Management (ICZM).

- The Convention on the Protection of the Black Sea Against Pollution (Bucharest Convention), 1992 ratified by Turkey in 1994

The three Protocols on (i) the Protection of the Marine Environment of the Black Sea from Land-Based Sources and Activities, (ii) cooperation in combating pollution of the Black Sea marine environment by oil and other harmful substances in emergency situations, and (iii) the protection of the Black Sea marine environment against pollution by dumping, have been also ratified.

The economic sectors which use marine waters include: Aquaculture and mariculture, Shipping, Fisheries, Tourism, Oil and Gas, and Salt production. The legislative and regulatory framework and agreements related to marine waters cover:

- The International Convention for the Prevention of Pollution from Ships (MARPOL);
- International Convention on Civil Liability for Oil Pollution Damage (CLC);
- International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND);
- International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC);
- Barcelona Convention;
- Bucharest Convention;
- Environment Law;
- Law Pertaining to Principles of Emergency Response and Compensation for Damages in pollution of Marine Environment by Oil and Other Harmful Substances (OSRL);
- By-law on implementation of OSRL;

[18]https://www.joi.or.jp/modules/investment/custom/documents/TUR_EU_INTEGRATED_ENVIRONMENTAL_APPROXIMATION_STRATEGY.pdf
[19] http://www.ecranetwork.org/Files/Workshop_Report_MSFD,_May_2015,_Istanbul.pdf

- By- law on Quality of Bathing waters;
- By-law on Reception of Wastes from Ships and Waste Control Regulation.
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Since 2011 all monitoring systems for marine water quality were integrated with an ecosystem based approach. Currently over 40 parameters are monitored twice a year at nearly 250 points.

Environmental quality standards (EQS) are developed and they will be adopted through a by-law. Within the frame of some projects (like DeKoS[20]), the pressures and impacted areas were analysed and action plans with measures were prepared to control pressures for all Turkish coastal and marine waters.

The measures taken for the protection of the inland water quality and those of the marine water quality are economically assessed. Turkey is making use of the following legal international and EU instruments and policies: Common Fisheries Policy (CFP), Integrated Maritime Policy (IMP), Common Agricultural Policy(CAP), Natura 2000 Directive, Birds Directive, Habitats Directive, Water Framework Directive(WFD), Nitrates Directive, and International Convention for the Prevention of Pollution from Ships (MARPOL), the Barcelona Convention, and the Bucharest Convention.

Due to the creation of the two new Ministries there is a significant degree of overlapping authorities which need to be resolved. This is particularly the case in regard to protected areas. Up to 2013, marine protected areas were under the authority of the MoEU and the Directorate of Natural Resources. However, there was work underway to revise the entire Turkish environmental legislation and regulations to address the problems that have arisen from overlapping authority. Then the Authority has changed and Ministry of Environment and Urbanization became responsible for MSFD steps. The Project Fische is a good example for this situation. Ministry of Environment and Urbanization, General Directorate of Environmental Management, Department of Marine and Coastal Management was the responsible authority. The National Biodiversity Strategic Action Plan (NBSAP) is based on the following five assumptions: biodiversity is the biological foundation for sustainable development; biodiversity is in jeopardy; conserving biodiversity is a shared responsibility; biodiversity links to future prosperity; and Turkey contributes to global biodiversity conservation. Turkey‘s NBSAP comprises 6 goals; conservation and sustainable use; ecological management; education and awareness; incentives and legislation; International Cooperation and implementation. The NBSAP2001 was updated in 2007 (active for 2008-2017).

[20] http://durak.mam.gov.tr/dekos/

Current Turkish laws and by-laws which relate to conservation of GES can be listed as follows; Turkish Constitution (9.11.1982), Environmental Law (9.8.1983), Harbours Law (14.4.1923), Coastal Law (4.4.1990, Amendment 1.7.1992), Fisheries Law (22.3.1971, Amendments (15.5.1986), National Parks Law (9.8.1983), Law for Protection and Cultural and Natural Wealth (21.7.1983), Council of Ministers Decree for Agency for Specially Protected Areas (19.10.1989), Bosporus law (18.11.1983), Coastal security force law (9.7.1982), Settlements law (3.5.1985), Tourism Incentives Law (12.3.1982), (2003) Forestry Law (31.8.1956; Amendments, 23.9.1983).

The latest grant for the negotiation process in Marine Strategy Framework Directive (MSFD)of EU (2008/56/EC) in Turkey was taken from EuropeAid[21], with the Project Technical assistance for capacity building on Marine Strategy Framework Directive in Turkey- 2014/S 166-295692- EuropeAid/135965/IH/SER/TR.

The purpose of the Project was to develop necessary institutional and technical capacity for the transposition and implementation of the Marine Strategy Framework Directive (MSFD) 2008/56/EC in Turkey by providing technical assistance services such as: preparing gap analysis and to produce some recommendations for the coherent coordination among the related institutions, developing methodology regarding the implementation of the Directive, training, study visit and workshop activities. National Authority of this project was Central Finance and Contracts Unit (CFCU), Ankara, Turkey. External aid programmes of EU was used and maximum budget for this call was given as 2 500 000 EUR. The Project Fiche used this budget for under going projects under the supervision of Republic of Turkey's Prime Ministry Under Secreteriat of Treasuary Central Finance &Contract Unit /CFCU). This project will give an overview of the present discrepancy and thus, elaborates more on the need of having broader knowledge between Turkish marine management and the EU requirements. And also, it would support the establishment of the programme of measures within the scope of MSFD in a good manner. These will enable the beneficiaries to plan the necessary investments and capacity building training. Via this project, determination of environmental objectives would also be performed.

Due to the Marine Strategy Framework Directive (MSFD)of EU (2008/56/EC), article 6[22] Regional cooperation part includes the West Aegean Sea . Article 6 declares that; in order to achieve the coordination referred to in Article 5(2), Member States shall, where practical and appropriate, use existing regional institutional cooperation structures, including those under Regional Sea Conventions, covering that marine region or subregion. For the purpose of establishing and implementing marine

[21] https://ec.europa.eu/europeaid/home_en

[22] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF

strategies, Member States shall, within each marine region or subregion, make every effort, using relevant international forums, including mechanisms and structures of Regional Sea Conventions, to coordinate their actions with third countries having sovereignty or jurisdiction over waters in the same marine region or subregion. In that context, Member States shall, as far as possible, build upon relevant existing programmes and activities developed in the framework of structures stemming from international agreements such as Regional Sea Conventions. So coordination and co-operation shall be extended, where appropriate, to all Member States in the catchment area of a marine region or subregion, including land-locked countries. In order to allow Member States within that marine region or subregion to meet their obligations under this Directive, using established cooperation structures prescribed in this Directive or in Directive 2000/60/EC[23].

Due to the Article 4 Black Sea and Mediterranean Sea were considered as marine regions and under the Mediterranean Sea, West Mediterranean Sea and the Aegean-Levantine Sea were defined as marine subregions which were shared with member states and Turkey. With using this opportunity Turkey became in part in some EU funded projects for Black Sea. In the future possible collobrations may be with Greece for the common sea Aegean Sea.

5. Aegean Sea and MSFD

The Aegean Sea placing in the northeast part of the Mediterranean Sea, centered at approximately 25 ºE and 38 ºN lying between Turkey (East part) and the mainland of Greece at the west and north margin. It is bounded in the south by an arc extending along the Greek islands of Rhodes near the Turkish mainland (Fethiye).

The Aegean is connected to the Black Sea via a narrow straight, the Çanakkale (55 m deep, 0.45-7.4 km wide), the small Sea of Marmara and a second narrow strait, the Bosphorus. The Aegean receives around 190 km3 per year of water from the Black Sea. Currents carry the less saline water of the Black Sea at and near the surface, while lower down more saline water of the Mediterranean flows in the opposite direction.

As mentioned in this section before, Turkey be a part in several EU projects about MSFD with neigbour countries which were almost releated to Black Sea and East Mediterreanean Sea. About Aeagean Sea "DeKoS Project" can be a good example in this case. Although Project DeKoS is relating with all the coastal sides of Turkey, project team collected all GES criterias about the East Aegean Sea. The MSFD related aim of the project was to define national GES objectives, focusing on the determination

[23] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

of data, monitoring and evaluation requirements (TUBITAK-MRC & MoEU-GDEM, 2014). Major outputs of the DeKoS project for the MSFD can be summarised as follows;

- Integrated Marine Monitoring and Assessment Programme (IMMAP)' was developed, which takes account of the requirements of RSCs, in addition to EU Directives (e.g. MSFD and WFD), establishing its principles, sets of criteria and inputs for institutional arrangements, guidelines and legal arrangements for national marine monitoring. This is now in action by increased station and parameter numbers, representing all defined water bodies.
- Establishment of a national 'marine database', which is coherent with international databases, pressure/pollution/ecosystem quality GIS maps and development and/or adaptation of 'assessment tools' for coastal waters such as indexes, indicators, ecological quality classification measures, etc.
- Preliminary analysis of GES for Turkish marine environments within the frame of the 11 GES descriptors and recommendations for national GES objectives
- Determination of 15 national MSFD sub-regions on the bases of hydromorphology, pressure and state assessments.
- In addition, the project promotes the inclusion of new parameters such as micro-plastics and radioactivity; the spatial coverage of marine monitoring system now comprises all 75 water bodies which was only 57 until 2014[24].

In Turkey many projects have been planned under the Environment Chapter of EU membership negotiations, which are directly or indirectly related with MSFD. But the project entitled 'Capacity building on Marine Strategy Framework Directive in Turkey'[25] is directly related to MSFD and aims to develop administrative and technical capacity building for the adaptation to and implementation of the MSFD in all costal sides of Turkey. One of the major aims of the project was the assessment of legislative and administrative state in Turkey for the MSFD, and preparation of guidelines for the implementation of the MSFD in two pilot areas, the Mediterranean (including Eastern Aegean Sea) and the Black Seas.

The relevant legislation conformity has not yet been established for the MSFD in Turkey, with legislative, administrative and institutional arrangements/adjustments being within their initial stages. Some country-specific barriers for the implementation of MSFD and its assessment of the descriptors in Turkey, primarily concern the barriers related with the governance. The Ministry of Environment and Urbanization is the national authority for the implementation of the MSFD, whereas the Ministry for EU Affairs and the Ministry of Foreign Affairs are responsible for international

[24] Kaboglu et al, 2014.

[25] http://www.ims.metu.edu.tr/Sayfa.php?icerik=Makale&mid=15

coordination. Although the Ministry of Forestry and Water Affairs deals specifically with WFD, it also has partial authority on the implementation of MSFD related issues, especially in the geographically intersection areas (coastal waters). Additionally, the Ministry of Food, Agriculture and Livestock is responsible for fisheries and aquaculture and the Ministry of Transport, Maritime Affairs and Communications is the authority for shipping and other maritime activities. All these authorities have their own perspectives for the ecosystem goods and services, and thus for ecosystem based approach. Actually official report of the Project DeKoS still close to public but there are still many gaps in the Aegean Sea, with the support of these authorities and the academicians solutions can easily be found and many proposals can be prepeared for future proposals about Aegean Sea.

6. Related EU Projects about Meditereanean and Black Sea

With the overall objective, of ensuring progress towards achieving good environmental status in the Black Sea, and the specific objectives of promoting EU environmental objectives in the Black Sea region, and ensuring consistence and a high degree of convergence between the policy of the Convention on the Protection of the Black Sea Against Pollution (the Bucharest Convention) and EU acquis, namely, the Marine Framework Strategy Directive and its related Directives, the Commission on the Protection of the Black Sea Against Pollution and the European Commission concluded a Grant Agreement for "Support to the Black Sea Commission for the Implementation of the Marine Strategy"[26]. Several important documents have been developed with the consideration of the MSFD and the Black Sea Strategic Action Plan (BSSAP 2009). The templates for the State of Environment Report and for the Report on the Implementation of the Strategic Action Plan for the Environmental Protection of the Black Sea (2009) have been developed taking into consideration the MSFD reporting needs as well.

- Technical work in relationship to the MONINFO projects is completed; they aimed at deepening information and data exchange mechanisms among competent authorities and setting up and operating the necessary tools for prevention of and response to oil pollution from ships in the Black Sea. These projects have contributed to the development of a regional system against oil pollution from ships in the Black sea which will support the implementation of the Marine Strategy Framework Directive and provides a concrete proof of EU commitment and contribution in addressing key environmental threats in neighbouring regions.
- Environmental Monitoring for the Black Sea Basin: Monitoring and Information Systems for Reducing Oil Pollution – Phase 1

[26] http://ec.europa.eu/environment/marine/international-cooperation/regional-sea-conventions/bucharest/pdf/MSFD%20Draft%20Final%20Report.pdf

• Environmental Monitoring for the Black Sea Basin: Monitoring and Information Systems for Reducing Oil Pollution - Phase 2

• The project with the Black Sea Commission concerning implementation of the Marine Strategy has been finalised.

• The European Commission's Environment Directorate-General financially supports a number of projects related to marine and coastal environmental monitoring in the Black Sea:

• The MISIS Project[27] focuses on environmental monitoring in Bulgaria, Romania and Turkey and will contribute to enhancing the regional cooperation, directly adding to measures aimed for combating pollution and biodiversity decline in the Black Sea region, and for addressing negative effects of environmental degradation. A similar project for Ukraine, Russia and Georgia was launched in January 2013 by the European Commission's Directorate-General for Development and Cooperation - EuropeAid jointly with UNDP.

• The Black Sea Seabirds Projectaims to create the basis for an inventory of Marine Important Bird Areas (IBAs) for two seabird species. The Baltic2Black project aims to facilitate delivery of the Black Sea Commission integrated regional monitoring and assessment products, with focus on nutrient pollution and eutrophication.

And also the Project PERSEUS[28] is one of the largest marine environmental research project funded by the European Commission under Ocean of Tomorrow 2011-2015. Changes are occurring in our ecosystems, and with the aim that measures can be taken to turn back the tide on marine degradation. This is the focus of PERSEUS and science plays the leading role. PERSEUS is a one of a kind marine research project covering both the Mediterranean and Black Sea, together representing the Southern European Seas. List of the relevant EU projects in Meditereanean Sea and Black Sea and can be concluded as follows;

- http://ec.europa.eu/research/bioeconomy/fish/research/ocean/index_en.htm
- http://cordis.europa.eu/fp7/coordination/
- http://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020/index_en.htm
- http://www.kg.eurocean.org/
- http://www.devotes-project.eu/
- http://www.perseus-net.eu/site/content.php
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- http://www.envirogrids.net/

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27 http://www.misisproject.eu/

28 http://www.perseus-net.eu/site/content.php?locale=1&locale_j=en&sel=1

- http://www.seas-era.eu/np4/homepage.html

7. Conclusion

Many GES parameters have been determined by scientists in North Aegean Sea and all these data can be found in literature. Detailed knowledge could also be found in previous sections of the current book but national legislations and the Govermental strategy should be performed for Aegean Sea in Turkey. Aegean-Levantine Sea was defined as marine subregions due to the Article 4 in Turkish waters especially in Marine protected areas monitoring programs should be used to integrate the Marine Strategy Framework Directives of EC. Undertaken projects can be samples for future steps.

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Misis project web page available at; http://www.misisproject.eu/
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MARITIME BOUNDARIES IN THE AEGEAN SEA AND PROTECTION OF BIODIVERSITY

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The Aegean Sea is a sub-regional sea of the Mediterranean Sea and possesses the characteristics of an enclosed and semi-enclosed sea, as defined under article 122 of the 1982 United Nations Convention on the Law of the Sea (UNCLOS).[29] Bordering it are Turkey and Greece, the only two coastal states in the Aegean who share this narrow body of water that measures only four hundred nautical miles in length and less than four hundred nautical miles at its widest point. Lying between these two states are some 1800 islands, islets and rocks; the North Sporades, the Cyclades, the Strait region islands, the Saruhan Islands and the Menteşe Islands (Dodacenese). These last three clusters are also referred to as the Eastern Aegean Islands and lie in close proximity to the Turkish mainland.[30]

The current land boundaries of Turkey were established by the 1923 Lausanne Treaty of Peace[31]. The Lausanne Treaty of Peace, which is still in force, included provisions on the ownership of certain islands near the Turkish mainland. Article 12 of the Lausanne Peace Treaty affirmed Turkish sovereignty over the Eastern Aegean Islands of Bozcaada (Tenedos), Gökçeada (Imbros) and the Tavşan Islands in the northern Aegean Sea; and recognized Greek sovereignty over the islands of Lemnos, Samothrace, Mytilene, Chios, Samos and Nikaria in the southern part of the Aegean Sea.[9] Under Article 15 of the Treaty, Turkey renounced in favor of Italy all rights and title to fourteen islands.[32] Following World War II, in 1947, Italy ceded the Dodocanese

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[29] United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397
[30] Yüksel İnan and Yücel Acer, *The Aegean Dispute*, available at http://www.foreignpolicy.org.tr/documents/251202.pdf
[31] Treaty of Peace with Turkey Signed at Lausanne, July 24, 1923, 28 L.N.T.S. 11, reprinted in 18 Am. J. Int'l L. Supp. 4 (1924).
[32] Stamalia (Astrapalia), Rhodes (Rhodos), Calki (Kharki), Scarpanto, Casos (Casso), Piscopis (Tilos), Misiros (Nisyros), Calimnos (Kalymnos), Leros, Patmos, Lipsos (Lipso), Simi (Symi), Cos (Kos), Castellorizzo (Meis) and the dependent islets collectively referred to as the Dodecanese Islands. During the period when the Dodecanese Islands were in the possession of Italy, the delimitation of the maritime boundary between of the islet Castellorizzo (Meis) and the Turkish coast was submitted to the Permanent

and Castellorizzo (Meis) islands to Greece.[33] Among the matters in dispute between Greece and Turkey is sovereignty of certain islands, islets and rocks that are not expressly mentioned in the Treaty.

The 1923 Lausanne Treaty, however, was negotiated more than twenty years before President Truman made his historic proclamation on September 28, 1945, which set in motion one of the major territorial seaward expansions in modern history.[12] In 1923 the continental shelf carried no legal significance, nor did the concept of a two hundred nautical mile exclusive economic zone (EEZ) – a creation of the 1982 LOS Convention nearly sixty years after the conclusion of the Lausanne Peace Treaty. In 1923 the breadth of the territorial sea, according to customary international law at the time, was three nautical miles.[34] Article 6 of the Lausanne Treaty endorsed this understanding with a general provision that in the absence of provisions to the contrary, "islands and islets lying within three miles of the coast are included within the frontier of the coastal State." Article 12 repeated this rule specifically for Turkey; absent a provision to the contrary in the Treaty all islands "situated less than three miles" from the Turkish coast remained under Turkish sovereignty.

One of the most challenging maritime boundary disputes in international law began in 1973 in search of potential hydrocarbon reserves beneath the Aegean Sea continental shelf. Since 1973 the Greeks and the Turks have locked horns over territorial claims in the Aegean Sea,[35] coming very close on a number of occasions to military conflict, such as the incident that took place in 1996 over the ownership of a "rock."[16] The Aegean Sea maritime boundary dispute can be fairly described as a "frozen conflict" between Turkey and Greece and, like many of the delimitation conflicts, is about ownership of valuable natural resources, — in particular oil and gas.

The unresolved matter of maritime boundaries in the Aegean Sea between Greece and Turkey is decades old and encompasses a number of issues in dispute,

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Court of International Justice in 1929. The case was subsequently withdrawn by the Parties, who then concluded the 1932 Ankara Agreement.

[33] Treaty of Peace with Italy, Feb. 10, 1947, 49 U.N.T.S. 126.

[34] 1 Rene-Jean Dupuy and Daniel Vignes, A Handbook on the New Law of the Sea 5 (1991). *See also* 1 L. Oppenheim, International Law: A Treatise 255 (1st ed. 1905) on the three-mile rule, also referred to as the "cannon shot" or one-league rule.

[35] Aegean Sea Continental Shelf (Greece v. Turk.), 1978 I.C.J. 3 (Dec. 19). Greece initiated proceedings against Turkey before the International Court of Justice for the delimitation of the continental shelf with Turkey primarily because of Greek interest in oil exploration and exploitation. However, Turkey did not agree to the jurisdiction of the ICJ and the case was dismissed.

including disagreement as to which issues are "in dispute."[36] Greece has only recognized the dispute over the maritime boundaries of the continental shelf between mainland Turkey and the cluster of Greek islands hugging the Aegean coast of Turkey. Turkey disputes a multitude of issues, including questions of unresolved sovereignty and the demilitarization of certain islands in the Aegean Sea, the breadth of the territorial sea, delimitation of the continental shelf, the Exclusive Economic Zone, and rights of navigation and over-flight in the Aegean Sea.

The Aegean Sea maritime boundary imbroglio, in addition to its political and legal marine area. This chapter will examine the international legal framework for the protection of the marine environment in the Aegean and the need for greater cooperation between the two coastal States.

The Marine Environment and Biodiversity

The current maritime boundaries of the Aegean Sea leave almost fifty percent as high seas.[37] The regime of the high seas under international law, as codified under UNCLOS provides that inter alia the high seas are open to all, in other words 'freedom of the high seas', such as freedom of navigation and freedom of fishing. While these freedoms are not absolute, only the flag State has the exclusive jurisdiction to enforce its laws against its own vessels on the high seas. This applies to the enforcement of other international agreements, such as the many IMO instruments for safety of shipping and protection of the marine environment from vessel-sources of pollution. The competence of States to establish, regulate and enforce marine protected areas in areas beyond the coastal State jurisdiction is also restricted.

Adopted in 1982 UNCLOS was hailed as the "Constitution for the Oceans" and remains as the only global instrument creating a framework for the protection of the marine environment and Part XII in particular.[38] Further, UNCLOS is the only global instrument that creates an unqualified binding legal obligation for States to protect and

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[36] Jon M. Van Dyke, *An Analysis of the Aegean Disputes Under International Law*, 36 Ocean Dev. & Int'l L. 63, (2005).

[37] The current six nautical mile territorial sea in the Aegean Sea provides Greece with control over 43.68 percent of the waters and Turkey with control over 7.47 percent.

[38] *See* McConnell & Gold, *supra* note 404; Boyle, *Marine Pollution under the Law of the Sea Convention*," *Supra* note 403; Christopher C. Joyner, *Biodiversity in the Marine Environment: Resource Implications for the law of the Sea,* 28 Van. J. Transnat'l L. 635, 656-663(1995), Erick Franckx, *Regional marine environment protection regimes in the context of UNCLOS*, 13 Int'l J. Mar. & Coastal L. 307 (1998).

[38] Article 207.

preserve the marine environment as stated in article 192.[39] While Greece is a party to UNCLOS, Turkey is not, however. The primary reason behind Turkey's opposition to the final text and its continued reluctance to ratify the Convention is the maritime delimitation quandary between itself and Greece in the Aegean Sea. Nonetheless, Turkey is obligated to protect the marine environment under customary international law. Part XII of the LOSC and the provisions, in particular the obligation to protect the marine environment under article 192, that are considered to constitute customary international law would arguably constitute such international obligations.[40]

Enclosed and semi-enclosed seas are by nature vulnerable marine ecosystems, and the Aegean Sea is no exception. Situated at the mouth of the Turkish Straits, the Aegean Sea is one of the most heavily transited straits used in international navigation, with over 50,000 vessels annually traveling between the Aegean Sea to the Black Sea through the Turkish Straits, of which over ten thousand are vessels transporting dangerous and hazardous cargo. The Turkish Straits, described as a "biological corridor"[41] linking the Black Sea to the Aegean Sea, provides an important ecological

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[39] Article 192 of the 1982 LOSC established that "[a]ll States have the duty to preserve and protect the marine environment." *See in general* McConnell & Gold, *supra* note 404. Jonathan I. Charney, *Impact of the Law of the Sea Convention on the Marine Environment*, 7 Georgetown Int'l Envt'l L. Rev. 732(1995); Miles 1997; Boyle *supra* note 403; Jon M. Van Dyke, *Giving Teeth to the Environmental Obligations of the LOS Convention*, in Oceans Management In The 21st Century: Institutional Frameworks And Responses, 167-186 (A.G.O. Elferink & Donald Rothwell eds., 2004).

[40] David Freestone, *The Conservation of Marine Ecosystems Under International Law*, in Internatıonal Law And The Conservatıon Of Bıologıcal Dıversıty 91 (Michael Bowman & Catherine Redgwell eds., 1996); Jon Van Dyke, *Giving Teeth to the Environmental Obligations in the LOS Convention*, In Oceans Management In The 21st Century: Instıtutıonal Frameworks And Responses 167–186 (Alex Oude Elferink & David Rothwell, eds., 2004); Alan Boyle, *Further Development of the 1982 Law of the Sea Convention: Mechanisms for Change,* 54 Int'l & Comp. L. Q 563-84 (2005); International Law Association (ILA), "Formation of General Customary International Law: Final Report", in Report of the 69th ILA Conference 712–790 (Alfred Soons & Christopher Ward, eds., 2000). Philomene Verlaan, *Geo-engineering, the Law of the Sea, and Climate Change,* 4 Carbon & Climate L.Rev. 446 (2009)

[41] Bayram Öztürk, *The Istanbul Strait, Closing a Biological Corridor*, in Ismail Soysal (ed.) Turkish Straits, New Problems New Solutions (1995)

waterway for fish stock and cetaceans. In addition to the threats brought with heavy maritime traffic, including vessel-source pollution and introduction of invasive species through ballast water, non-sustainable fishing practices, eutrophication, and the loss of biodiversity threaten the Aegean's marine living resources. In particular, the lack of robust legal regime, including monitoring and enforcement, in the high seas allows for illegal, unreported and unregulated fisheries of the bluefin tuna (*Thunnus thynnus),* albacore (*Thunnus alalunga*), bullet tuna (*Auxis rochei*) and swordfish (*Xphias gladius*), which are depleted species. Further, cetaceans are entangled in offshore driftnets.[42]

However, as high seas, the coastal State jurisdiction of both Greece and Turkey to enforce national and international regulations and standards in some 50% of the Aegean Sea is limited.

The Duty to Cooperate Under International Law

The duty to cooperate is a rule of customary international law. As stated by Kiss and Shelton, the general duty to cooperate "derives from the very essence of general international law….In the field of environmental protection, international co-operation is necessary to conserve the environment in its totality…"[43] The central role of cooperation for the protection of the environment was recognized by the 1972 Stockholm Declaration which in its preamble underlined that the "growing class of environmental problems, because they are regional or global in extent or because they affect the common international realm, will require extensive co-operation among nations and action by international organizations in the common interest."[44] Principle 24 of the Stockholm Declaration recognized that "[i]nternational matters concerning the protection and improvement of the environment should be handled in a cooperative spirit by all countries, big and small, on an equal footing. " and that [c]ooperation through multilateral or bilateral arrangements or other appropriate means is essential to effectively control, prevent, reduce and eliminate adverse environmental effects

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[42] Bayram Öztürk, *Marine protected areas in the high seas of the Aegean and Eastern Mediterranean Sea, some proposal*s, 15 Jrn'l of Black Sea/Mediterranean Sea Environment, (2009) 69-82.

[43] Alexandre Kiss & Dinah Shelton, International Environmental Law, 28 *supra* note 53. However, in favor of a more limited application of the duty of international cooperation in the case of major pollution incidents and security interests of States *see* P. T. Stoll, The International Environmental Law Of Cooperation In Enforcing Environmental Standards: Economic Mechanisms As Viable Means? (Rudiger Wolfrum, ed.,1996).

[44] Declaration of the United Nations Conference on the Human Environment, adopted in Stockholm during the United Nations Conference on the Human Environment, 5 to 16 June 1972. *Available at* http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=97&ArticleID=1503

resulting from activities conducted in all spheres, in such a way that due account is taken of the sovereignty and interests of all States. Principle 27 of the Rio Declaration ventured further to mandate cooperation; "States and people *shall* cooperate in good faith and in a spirit of partnership in the fulfillment of the principles embodied in this Declaration and in the further development of international law in the field of sustainable development." (Emphasis added)[45]

Article 123 of the 1982 UNCLOS exhorts coastal States bordering a semi-enclosed or enclosed sea, as defined in Article 122, to cooperate in the exercise of rights and performance of duties, with a special focus on the marine environment and scientific research. The general duty to cooperate is codified under Article 197 of the 1982 UNCLOS.

The importance of collective State action to protect and preserve the environment was highlighted in the historic Stockholm Declaration, adopted during the 1972 United Nations Conference on the Human Environment (UNCHE).[46] The 1972 Stockholm Conference laid the foundation for the establishment of the United Nations Environmental Programme (UNEP), a subsidiary organ of the United Nations,[47] whose purpose is to promote international cooperation in the field of environmental

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45 *Available at* http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=78&ArticleID=1163

46 UN Doc. 48/14, 16 June 1972, *reprinted in* 11 ILM 1416 (1972). U.N. General Assembly Resolution 2997 (XXVII) of December 15, 1972, on the institutional and financial arrangements for international environmental co operation, 12 ILM 433 (1973). See, Patricia Birnie, *The Development of International Environmental Law*, 3 Brit. J. Int'l Stud. 169-190 (1977).

47 UNEP was established under Article 22 of the United Charter. It is not a specialized agency of the United Nations as provided under Article 57 of the United Nations Charter. As a subsidiary organ of the United Nations UNEP lacks the autonomous status of UN specialized agencies, which limits its funding options to voluntary contributions, whereas a specialized agency has its own separate budget. *See* Said Mahmoudi, *The United Nations Environment Programme (UNEP)- An assessment,* 5 Asian Y.B.Int'l L. 175-198 (1995).

protection.[48] Modern environmental law rests upon the principle of "cooperation" among States, and it is the thread that stitches together the multitude of international and regional instruments that apply to the protection and preservation of the environment, including the marine environment. The cooperative foundation for addressing the environmental threat to the marine environment of the UNEP Regional Seas Programme was based directly on principle Article 24 of the Stockholm Declaration, which calls for multilateral co-operation to "control, prevent, reduce and eliminate adverse environmental effects."[49] This collective spirit of addressing environmental concerns is embodied in the notion introduced at the 1992 UNCED that the protection of the environment and its living resources is a 'common concern.'[50]

The UNEP Regional Seas Programmes, with eighteen regional seas programmes under its auspices, remains the principal regional mechanism for co-operation, creating an institutional and governance framework for the protection and preservation of the marine environment based on state co-operation at the regional level.[51]

UNEP Mediterranean Sea Programme

The UNEP Programme for the protection of the marine environment of the Mediterranean Sea was the first UNEP Regional Seas Programme.[52] The original Convention for the Protection of the Mediterranean Sea against Pollution that had been adopted in 1976 was amended and renamed in 1995 as the *Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean*

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48 UNEP's mandate also includes the progressive development of environmental law. *See* Alexander Timochenko, *UNEP Initiatives to Promote Compliance with Multilateral Environment Agreements," in* Economic Globalization And Compliance With International Environmental Agreements 125-137, 126 (Alexandre Kiss, Dinah Shelton & Kanami Ishibashi, eds., 2003).

49 G.A. Res. 2997, 27 U.N. GAOR Supp. (No. 30) at 30, U.N. Doc. A/8730 (1972);Peter C. Schroder, *UNEP's Regional Seas Programme and the UNCED Future: Apres Rio,* 18 OCEAN & COASTAL MGMT. 101-111 (1992); Mark Allen Gray, *The United Nations Environmental Programme: An Assessment,* 20 Envtl. L. 291 (1990).

50 Patricial Birnie, Alan Boyle & Catherine Redgwell International Law And The Environment 3rd Ed., 128-130 (2009).

51 Detailed information on the UNEP Regional Seas Programme *available at* http://www.unep.org/regionalseas/

52 For more information *see* http://www.unep.org/regionalseas/. *See also,* Vallega, *Regional Level Implementation of Chapter 17, supra* note 503.

("Barcelona Convention.").[53] The Mediterranean Protocols include: the Dumping Protocol, renamed the Protocol for the Prevention and Elimination of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea,[54] the Protocol in Cases of Emergency, Combating Pollution of the Mediterranean Sea ("Prevention and Emergency Protocol")[55] which replaced the Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency (Emergency Protocol); the 1976 the *Regional Oil Combating Centre for the Mediterranean Sea ("ROCC") was renamed as the* Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea ("REMPEC"). Other instruments adopted included the Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal ("Izmir Protocol"), the Protocol for Integrated Coastal Zone Management (ICZM Protocol),[56] representing the first ICZM instrument of all the regional seas programmes.

One of the innovative legal instruments adopted by the Contracting Parties to the Barcelona Convention was the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean ("SPA and Biodiversity Protocol"-or "SPAMI"), which replaced the Protocol concerning Mediterranean Specially Protected Areas. The new SPAMI Protocol provides for the collaborative establishment of marine protected areas between two or more Contracting Parties, and also created the possibility for the designation of marine protected areas in areas beyond national jurisdiction, with the consensus of the Contracting Parties.[57] As of 2015 there are a total of 33 SPAMI sites listed. However, the Pelagos Sanctuary for Mediterranean Marine Mammals (*ex* Ligurian Sea sanctuary), established under the SPAMI Protocol in 1999, is the only marine protected area in the Mediterranean Sea to include areas of the high sea.[58] There is no SPAMI in the Aegean Sea.[59]

On 11 September 2009 the EC, as part of implementing its 2008 Marine Strategy Framework Directive adopted the Communication "Towards an Integrated Maritime

53 10 June 1995.
54 10 June 1995.
55 25 Jan. 2002.
56 21 Jan. 2008, a*vailable at* http://195.97.36.231/dbases/webdocs/BCP/ProtocolICZM08_eng.pdf
57 Tullio Scovazzi, *Marine Protected Areas on the High Seas: Some Legal and Policy Considerations*, 19 Int'l J. Mar. & Coastal L. 1-17 (2004).
58 Tullio Scovazzi, *The Mediterranean Marine Mammals Sanctuary*" 16 Int'l J. Mar. & Coastal L 132 – 145 (2001).
59 See SPAMI map at http://www.rac-spa.org/sites/default/files/doc_spamis/spamis_2015.pdf

Policy for better governance in the Mediterranean Sea."[60] The Mediterranean Sea presents a greater challenge in regional governance in many respects from other regional seas. With more than twenty coastal States bordering the sea and the uneven socio-economic levels in the Mediterranean the achievement of coordinated and harmonized standards of protection of the marine environment is problematic. With this in mind, the EC has proposed a strategy that seeks to promote enhanced coordination and harmonization in the implementation of international and regional norms at the national levels. The EU adopted the Integrated Maritime Policy for the Mediterranean Sea as the first step in this process, the objective of which is to improve maritime governance through an integrated approach to different uses of the seas by adopting crosscutting tools of governance.

The Integrated Mediterranean Policy, while primarily aimed at Member States, also seeks to promote greater co-operation between the EU Members States and non-EU Member States bordering the Mediterranean Sea. Key to its strategy for creating an integrated system of maritime governance for the Mediterranean Sea, the Communication identified two tools: marine spatial planning and the use of marine strategies. The Communication noted the need for "shared and …integrated responses" for promoting improved maritime governance in the Mediterranean, highlighting the central role of co-operation.

Cooperation in the Aegean Sea

The maritime boundary imbroglio has cast dark shadows over the Aegean Sea for decades and resolution is not immediately apparent leaving some 50% of as high seas and beyond the protection of the coastal States. Meanwhile, threats to the biodiversity of this sensitive sea continue. The duty to cooperate applies all aspects of international and neighborly relations. Given the clear obligation under customary international law and UNCLOS, Greece and Turkey should give serious consideration to establishing a cooperative mechanism to protect the biodiversity of the Aegean Sea. The SPAMI, such as established for the Pelagos Sanctuary, provides one option for the two coastal States. Without prejudicing the legal positions of the two Aegean States, a jointly designated and managed specially protected area marine area would not only serve the common interests of both Greece and Turkey to protect and preserve the unique and vulnerable marine environment of the Aegean Sea but also provide a strong message of cooperation that transcends the decades old boundary dispute.[61]

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[60] Towards an Integrated Maritime Policy for better governance in the Mediterranean, COM (2009) 466 final.

[61] See also Öztürk *supra* note 14.

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ISBN 978-975-8825-33-2