PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

VLIZ

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Integrated Marine Research in the Mediterranean and the Black Sea

Conference Proceedings

Brussels 7-9 December 2015

Scientific Conference
“Integrated Marine Research in the Mediterranean and the Black Sea”

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Editors

The research leading to these results has received funding from the European Union's Seventh Framework Programme [FP7/2007- 2013] under grant agreement n° 287600 project PERSEUS (Policy- oriented marine Environmental Research for the Southern European Seas)

Preface

Seas and oceans are an indispensible part of our lives. If we consider that "every second breath comes from the ocean"…. then we will realise how important it is to have clean and healthy seas and oceans, now and in the future…. On the other hand, human activities show increasing pressures on the oceans and generate a number of threats to the marine environment. These threats have inevitably jeopardized the future uses of the marine ecosystem's goods and services.

At European level, the Marine Strategy Framework Directive (MSFD) highlights the significance of protecting and preserving the marine environment of all European Seas and simultaneously promoting their sustainable use.

PERSEUS (Policy-oriented marine Environmental Research in the Southern European Seas, 2012-2015), one of the Projects of "The Ocean of Tomorrow" cross-thematic call of FP7, aimed to merge natural and socioeconomic sciences in an ecosystem approach to sustainable marine environmental management in the Mediterranean and Black Sea, in accordance with the MSFD principles. PERSEUS gave the scientific community a unique opportunity to 'translate' scientific knowledge into evidence-based policy recommendations, for the better governance of the Southern European Seas (SES) and, we hope, has created a strong platform for international scientific cooperation across seas, countries, institutes and scientists.

This volume includes the 120 papers (43 Short Communication and 77 Extended Abstracts), presented during the Final Scientific Conference of PERSEUS "Integrated Marine Research in the Mediterranean and the Black Sea", co-organized with the Flanders Marine Institute (VLIZ) and Flanders Department of Economy, Science and Innovation (EWI), in Brussels, in December 2015. The vast majority of these papers, originated through PERSEUS's work, have tried to give a multinational and multidisciplinary approach to the assessment of pressures, processes and impacts on the SES waters and to help policy-makers understand the potential of scientific advice to make informed decisions.

Four keynote speakers have been invited to deliver their messages on: mapping and role of organisations, important for the European marine and maritime landscape; preparation of guidelines for the institution of Networks of Marine Protected Areas (MPAs) in the SES, testing also the feasibility of Offshore Wind Farms; the activities of the IOOS (U.S. Integrated Ocean Observing System (IOOS®) as an operational and effective smart network; and making the most effective use of the scientific knowledge for societal benefits.

Finally, during the Conference two Round tables were organized with the following themes:

"European Marine Research Infrastructures: Their development and uptake for better science" &

"Where do we go from here in the SES?".

The outcomes can be found on the project's website www.perseus-net.eu .

I am confident that we have done our best in connecting science and policy and we are all convinced that the results and tools we have created can be used to achieve/maintain GES in the Southern European Seas.

Vangelis Papathanassiou,
Coordinator of PERSEUS

Acknowledgments

The research leading to this volume has received funding from the 7th Framework Programme, under Grant Agreement no 287600 - Ocean of Tomorrow (FP7-OCEAN) call in FP7.

We would like to thank the two Project Officers of the European Commission, Ana Teresa Caetano and Ariana Nastaseanu (2012-2013) for their valuable and constant support throughout the whole duration of the PERSEUS project.

Credits and thanks must be given to the Scientific Steering Committee of PERSEUS, Xavier Durrieu de Madron, Jean-Francois Cadiou, Joaquin Tintore, Marco Zavatarelli, Celia Vassilopoulou, Gheorghe Oaie, Didier Sauzade, Constantino Cosmidis, Aldo Drago, Alan Deidun, Emily Koulouvaris, Javier Ruiz, Alessandro Crise, Eleni Kaberi, Andrey Zatsepin and Mihalis Skourtos, for their steering and help in achieving the goals of the project. Thanks also to Laura Prieto, Emma Heslop, Areti Kontoyanni and Daniela Vasile, who helped the Steering Committee in coordinating various project activities.

We wish to express our gratitude to the PERSEUS Advisory Board composed of Fokion Vosniakos, Luis Valdes, Tatiana Hema, Niall McDonough, Irina Makarenko, Halil Ibrahim Sur, Mihalis Papadoyannakis, Anita Vella, Christos Theophilou, Frederic Briand and Trine Christiansen for their guidance during the project's lifetime.

Furthermore, we thank our colleagues from the Management Office, Mirto Kimigeli, Roula Frangou, Martha Papathanassiou and Claudia Cesarini for their continuous and valuable support throughout the project.

Finally, and regarding this volume, we recognize the effort made by all authors as well as the manuscript reviewers, who provided valuable comments that have contributed to the quality, clarity and scientific accuracy of the information provided herein.

The Editors

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Invited Speakers

Dr. Luis VALDÉS SANTURIO (Spain) is, since January 2009, the Head of Ocean Sciences at the Intergovernmental Oceanographic Commission of UNESCO, and formerly (2000-2008) he has been the Director of the Centro Oceanográfico de Gijón - Instituto Español de Oceanografía (CO Gijón-IEO). With more than 30 years of experience in marine research and field studies related with marine ecology and climate change, he established in 1990 the time series programme based on ocean sampling sites and marine observatories which is maintained by Spain in the North Atlantic. He has advised various governmental, intergovernmental and international organizations as well as research funding agencies. He has a vast experience in ICES where he has chaired different Working Groups and Committees including the Oceanographic Committee. He also served as Spanish Delegate in ICES and in the IOC-UNESCO.

Mapping European Marine/Maritime Landscape

Europe is a vast land space surrounded by four regional seas: The Baltic Sea, the North Sea, the Mediterranean Sea and the Black Sea. Over 2/3 of the EU’s continental borders are coastal with a total of 65,993 km of coastline (mostly in the Atlantic but also the Arctic Ocean borders the northern coasts of Europe) and the maritime spaces under the MSs jurisdiction are much larger than their terrestrial territory. Through its outermost regions, the EU is also present in the Indian Ocean, Pacific and the Caribbean Sea.

The European Community is a Party to three of the four regional sea conventions (HELCOM, OSPAR, and Barcelona Convention) and Bulgaria and Romania are members of the Bucharest Convention. There are four high level intergovernmental commissions that intervene in ocean sciences in Europe: the Arctic Council, the International Council for the Exploration of the Sea (ICES), the Mediterranean Science Commission CIESM and the Black Sea Commission (BSC). And several Regional Fisheries organizations intervene in the management of European fish stocks (NEAFC, GFCM, NASCO and ICCAT).

Europe is also involved in international conventions (e.g. London Convention/Protocol, UNFCCC, Stockholm Convention, CBD, CITES, etc.) and produce its own legal framework and directives on marine and maritime policies. The European Commission has developed its own agencies (EEA, EMSA, EFCA, JRC, REA) and also the ESA runs programmes related with the observation of the oceans.

There are many more organizations that are important for the European marine/maritime landscape and it is a challenge to summarize their roles in a systematic, relational and useful way that makes the figure understandable for the scientific community, the stakeholders and the decision makers.

In this talk a proposal to map the European marine and maritime landscape will be presented and discussed.

Dr Ferdinando Boero is: Professor of Zoology at the University of Salento, Italy; Associate to CNR-ISMAR; President of the Scientific Council of the Zoological Station Anton Dohrn, Naples; Representative of CoNISMa in the European Marine Board. Member of EASAC for the preparation of two key documents: Marine Sustainability in an age of changing oceans and seas; Future of the Ocean: impact of human activities on marine systems; Member of Faculty of 1000; Coordinator of the Ocean of Tomorrow project CoCoNet, on networks of Marine Protected Areas in the Mediterranean and Black Sea and the feasibility of OWF (involving 22 states in 3 continents). His Research interests are: Marine biodiversity and ecosystem functioning. MPAs. Evolution. Citizen Science. Communication in science. Main honors: Prix Manley Bendall, Grand Medaille Albert 1er for Oceanography of the Institute Océanographique de Paris.

CoCoNet, MPA networks and the Cells of Ecosystem Functioning

The production of guidelines for the institution of Networks of Marine Protected Areas (MPAs) in the Mediterranean and the Black Seas is the main product of the EU project CoCoNet, together with a smart wind chart to test the feasibility of Off Shore Wind Farms in the both basins.

Networks of MPAs are much different than single MPAs. They should cover the space in between MPAs, where conditions might not be those that induced the realization of MPAs. But the MPAs are not islands, and their biota survives because they are nested into larger ecosystems. It is tenuous to protect a restricted area if the rest is degraded. Our first question was to identify units of management and conservation, and then we had to state the objectives of conservation. The Habitats Directive of the EU recognizes only nine marine habitats, and they are all benthic. MPAs are “areas”, but the marine environment is a volume. The water column is the most widespread habitat of the planet, and it has been forgotten as such, in the Habitats Directive. The answer to the first question, then, was to identify proper volumes as units of management and conservation. They are the Cells of Ecosystem Functioning, a concept based on the possibility that oceanographic and bottom features define volumes where ecological processes are more tightly connected than they are with neighbouring volumes. These volumes are defined by upwellings, downwellings, gyres, eddies, fronts. But physics is just the framework, and then the structure and function of ecosystems are to be assessed. This was done by studying biodiversity distribution and connectivity. Once the units are identified, the state of the systems is to be evaluated. Good Environmental Status, as prescribed by the 11 descriptors considered by the Marine Strategy Framework Directive, is based on biodiversity and ecosystem functioning. There is not much to be proposed, further than that. So, for CoCoNet, the aim of networks of MPAs is to define the space, and this is done with the identification of the Cells of Ecosystem Functioning, and the objectives, and this is done by reaching and maintaining GES. The networks of MPAs will be a tool to achieve GES and to assess it, becoming a part of a much needed observation system that calls for the measurement of the 11 Descriptors of GES, none being actually measured with current monitoring systems that, of course, must be maintained and sustained but that need a timely upgrade to cover the requirements imposed by the Marine Strategy for the measurement of Good Environmental Status.

Zdenka Saba Willis, a member of Senior Executive Service, is the Director of the U.S. Integrated Ocean Observing System (IOOS®) Program. Prior to her assignment as Director of U.S. IOOS Program, Ms. Willis served as Director of NOAA's National Oceanographic Data Center. Ms. Willis is a retired Navy Captain with career service as a Meteorology and Oceanography officer in the United States Navy. Her tours include Naval Deputy to NOAA; Director National Ice Center; Office in Charge of the Naval Oceanography Command Detachment, Oceana Virginia and forecaster at the Naval Eastern Oceanography Center, Norfolk Virginia. Ms. Willis has a background in the collection of oceanographic data onboard the USNS Harkness and USNS Maury survey vessels and in the electronic navigational charting as Deputy Navigator of the Navy. Her other relevant Naval positions are the director of the Strategic Policy Forum (a Congressional and Executive Branch crisis simulation for Members of Congress, senior Executive branch officials, and military leaders) and adjunct professor in the Strategic Leadership Department at the Industrial College for the Armed Forces. Ms Willis received her Bachelor's Degree in Marine Science from the University of South Carolina. She received a Master's degree in Meteorology and Oceanography from the Naval Postgraduate, and a Master's Degree in National Strategy from the Industrial College of the Armed Forces.

U.S. Integrated Ocean Observing System (IOOS®) - Eyes on our Ocean

Whether we are talking about the Blue Economy, or resilient communities, we need smart investments in monitoring and observations. Observations are essential in the providing environmental information to ensure that we have a sustainable Blue Economy and are the bedrock of ready, responsive and resilient communities. The United States Integrated Ocean Observing System (IOOS®) is a user-driven, coordinated network of people, organizations, and technology that generate and disseminate continuous data about our coastal waters, Great Lakes, and oceans supported by strong research and development activities. IOOS is our Eyes on our Ocean to track, predict, manage, and adapt to changes in our marine environment and deliver critical information to decision makers to improve safety, enhance our economy and protect our environment.

Professor Anil Markandya has a PhD from the London School of Economics and has taught at University College London at Bath University in the UK and at Harvard University in the USA. He was a lead author for Chapters of the 3rd, 4th and 5th IPCC Assessment Reports on Climate Change and has worked extensively on natural resource valuation through TEEB and various international bodies. In 2008 he was nominated by Cambridge University as one of the top 50 contributors to thinking on sustainability in the world. Currently he is the President of the European Association of Environmental and Resource Economics, Member of the Scientific Council of the EEA and Scientific Director and Distinguished Ikerbasque Professor at the Basque Centre for Climate Change in Spain.

Science in Policy- Making
How to Make the Best of the Growing but Incomplete Knowledge Base

Science offers many opportunities for innovation and growth to position Europe as a front runner in a closed loop circular economy, enhancing its international industrial competitiveness through resource productivity and improving its position for resource efficiency technology, products and services. However, the policy system is complex and scientific evidence is not the only factor in the making of a policy decision. Moreover misuse of science can orient policy seriously in the wrong direction.

There is a need to create societal value and inter-generational sustainability, not just economic value. The development of effective science-policy and science-society interfaces at all levels of governance is essential in shaping environmental decision-making. Growing awareness of the importance of links between science and policy has triggered a range of initiatives, which have helped communicate complex scientific information to all stakeholders and contributed to an open and well-informed debate on the options. International examples include the International Panel for Climate Change, The Intergovernmental Platform on Biodiversity and Ecosystem Services and the Intergovernmental Oceanographic Commission of UNESCO. The speech will say something on the role of these organizations in conveying scientific information to policy makers and the impact it has had on decision-making and the challenges they have faced.

As part of EU environment policy, some very complex and sensitive issues are being addressed with impacts on biodiversity, society and the economy. In recent years, considerable progress has been made to improve and share the evidence base required to tackle such issues, for example through the development of Environment Data Centres and Biodiversity Information System for Europe, the work of the European Environment Agency, the Joint Research Centre, Eurostat, and research activities funded by EU Framework Programmes and Horizon 2020.

In spite of this, science is not used effectively in policymaking and knowledge that effects decision-making can still be woefully inadequate. Decision-makers deal with diverging scientific interpretations of facts, different sources of knowledge, values and understanding. They face the challenge of distinguishing information from disinformation, which may reflect different interests and opinions among stakeholders and within society, on important issues. The presentation will offer some suggestions to overcome the obstacles we face in making the most effective use of our vast scientific knowledge to guide society to make the best decisions given the challenges it faces.

Short Communications

Session 1

Trends of pH decrease in the Mediterranean Sea through sustained observations in the Strait of Gibraltar

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Abstract

A significant fraction of the CO_2 emitted to the atmosphere is absorbed by the oceans, causing ocean acidification (OA). Continuous pH and pCO_2measurements in the Mediterranean Sea have been performed during 3 years at the Strait of Gibraltar through autonomous sensors deployed at the GIFT time series in order to identify OA trends. A decreasing annual rate of -0.0044±0.00006 was found in the pH of the Mediterranean outflow (MOW). By modelling, the pH values of the Levantine Intermediate Water (LIW) and the Western Mediterranean Deep Water (WMDW) could be discriminated, which also exhibited a clear decline with time.
Keywords: Mediterranean outflow water, ocean acidification

1.Introduction

The oceans have taken up a significant part of the CO_2 that has been emitted to the atmosphere since the beginning of the industrial revolution by anthropogenic activities. Over the past 200 years, the global ocean has been responsible for the withdrawal of about 30 % of the anthropogenic carbon emissions (Le Queré et al., 2014). This sequestration of CO_2 has drastic consequences for the marine environment, as it leads to a pH decrease in seawater, which is referred to as ocean acidification (OA) (Doney et al., 2009). Accordingly OA is defined as the addition of carbon dioxide in seawater that causes a reduction in ocean pH and shifts in carbonate speciation. Due to its semi-confined nature and its biogeochemical peculiarities, the Mediterranean Sea has been suggested to represent one of the world's most sensitive ocean regions to OA. Considerable efforts have been made over the last decade to characterize the carbonate system in the Mediterranean (Rivaro et al., 2010, Touratier et al., 2012, Alvarez et al., 2014), to explore how much anthropogenic CO_2 has been already incorporated by the basin (Huertas et al., 2009, Schneider et al., 2010) and to estimate the corresponding pH decrease (Palmieri et al., 2015, Hassoun et al., 2015). Most of works are based on discrete data sets that span for a specific period of time or deal with a particular sub-region, which have lead sometimes to discrepant conclusions. In this work, we use pH measurements taken at the GIFT time series that is located in the Strait of Gibraltar to assess temporal trends of pH change in Mediterranean waters. Data were obtained at a high sampling frequency by moored autonomous sensors. The Strait of Gibraltar is the only connection between the Atlantic Ocean and the Mediterranean, representing then a privileged site where to monitor the evolution and response of the basin to anthropogenic perturbations. The circulation in the Strait can be approximated to a two-layer system: a surface eastward inflow of Atlantic water (AW) and a deep westward outflow of Mediterranean Outflow Water (MOW). The MOW is a mixture of intermediate and deep waters residing in the Mediterranean Sea, the Western Mediterranean Deep Water (WMDW), and the Levantine Intermediate Water (LIW),which originate in the Gulf of Lions and in the Levantine basin, respectively. It has been reported that both water masses occur in changing proportions throughout the year (García-Lafuente et al., 2007). This temporal variation in the water masses proportion within the MOW is expected to be reflected in the dynamics of the carbon system parameters. Results presented here correspond to the first continuous pH records at a high temporal resolution registered in the Mediterranean water at the Strait from August 2012 to June 2015. Our work provides the first rates of pH decrease in the MOW and in its forming water masses separately, which can be considered an indication of OA in the basin (Flecha et al., 2015).

2. Materials and methods

Submersible autonomous instruments to continuously measure pH and CO_2 (SAMI sensors) were deployed in a mooring line. Precision and accuracy of measurements were < 0.001 and ± 0.003 pH units and < 1 ppm and ± 3 ppm for SAMI pH and pCO_2 devices, respectively. They were placed around 13 m above the sea bottom (360 m depth) along with a CT (Conductivity Temperature) SBE 37 probe. The line alsocontained an uplooking acoustic Doppler current profiler (ADCP), and a currentmeter Nortek AQD to record water transport. The fraction of the water masses forming the MOW was obtained by an Optimum MultiParameter (OMP) analysis (Poole and Tomczak, 1999), with temperature and salinity being chosen as end members. pH was modelled by performing a Multiple Linear Regression (MLR) least square fitting, with the fraction of the three water masses that can be found in the Strait, being used as predictors. Data were averaged in periods of 84 hours, as our work focuses on long-term variability relevant for OA signals. SAMI-pH data were validated with periodically laboratory calibrations by using Certified Reference Material (CRM supplied by Prof. Andrew Dickson, Scripps Institution of Oceanography, La Jolla, CA, USA) and a Shimadzu UV-2401PC spectrophotometer containing a 25 °C-thermostated cells holder following a spectrophotometric method (Clayton and Byrne, 1993). In addition, the drift of 0.001pH units over 6 months obtained by the manufacturer was applied to the data.

3. Results

The variability of the fractions of the water masses forming the MOW that were discriminated with an OMP analysis clearly shows seasonal and interannual fluctuations (Fig. 1). During the monitoring period, the LIW seemed to dominate the outflow, with a mean fraction of 0.55±0.1 (Fig. 1) whereas the WMDW represented a fraction of 0.36±0.1 (Fig. 1). The presence of the AW (Fig. 1) was almost negligible within the MOW, at an average fraction of 0.09±0.0. Modelled pH data through a linear combination of these fractions clearly reproduced *in situ* values and discrepancies between them were in the order of ±0.005 pH units (Fig. 2). Averaging such discrepancies to a 6 h period (Fig. 2b), residuals followed the tidal cycle pattern (Fig 2), thereby confirming that tidal variability was excluded in our estimations.The pH data series clearly depicts a negative trend (Fig. 2a) although the data gap present after the first period due to batteries failure (April-June 2013) seems to visually break the tendency. From June 2013 onwards, the decreasing trend was even more evident. Taking into account the whole series, a pH-time linear regression was calculated (Fig. 3), yielding a ΔpH o -0.0044 units per year in the MOW (pH_{MOW} =-0.0044±6.2094*10^{-5}t+7.8987±9.1824*10^{-5},r^2=0.2362;p<0.01;n=15937).

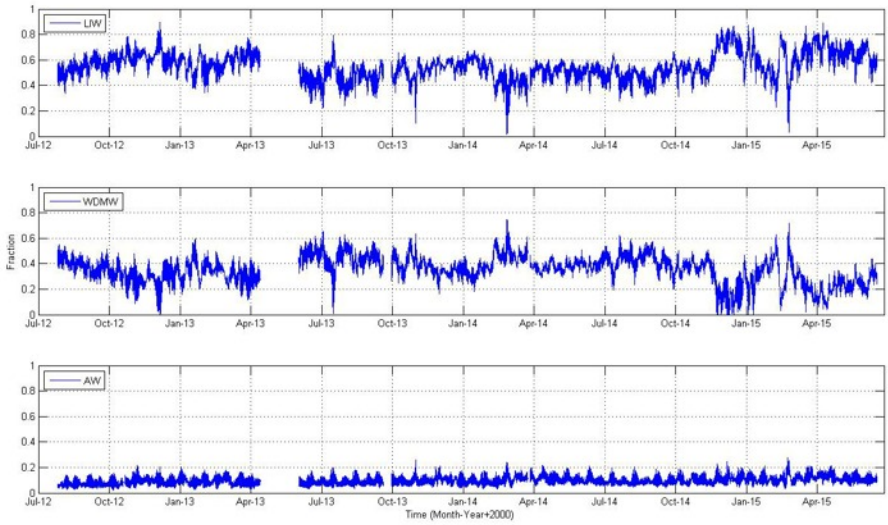

Fig.1 *Water masses fractions within the MOW obtained by an OMP analysis.*

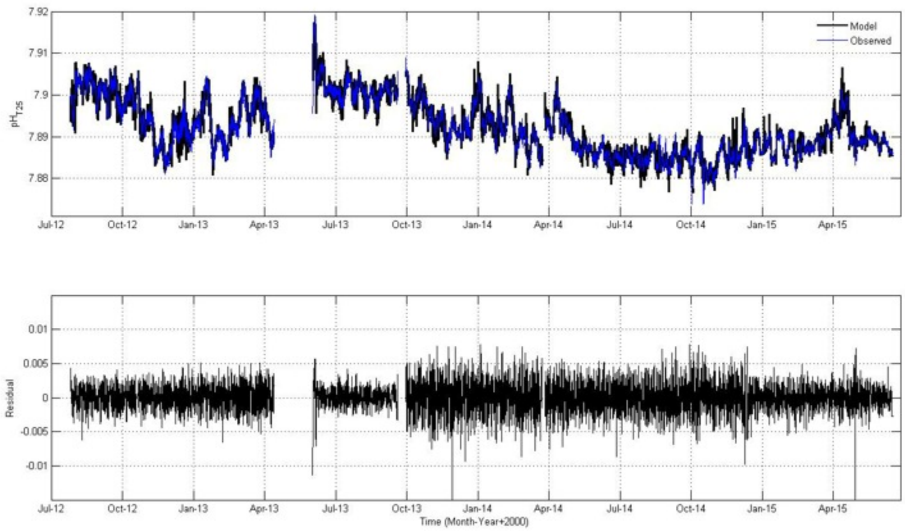

Fig. 2. *pH_{T25} obtained with the SAMI device (blue line) and modelled pH_{T25} (black line), Residuals between observed values and modelled outputs.*

Performing separate linear regressions of pH versus time for each of the two main water masses forming the MOW, annual decline rates of -0.0006 and -0.0165 pH units per year were obtained for the LIW and WMDW, respectively (pH_{WMDW} = -0.0165±0.0002 t + 7.9276±0.0003, r^2 = 0.2946, p<0.01, n=15937; pH_{LIW} = -0.0006±0.0001 t + 7.8822±0.0002 , r^2 = 0.0011, p<0.01, n=15937, Fig. 3b and c).

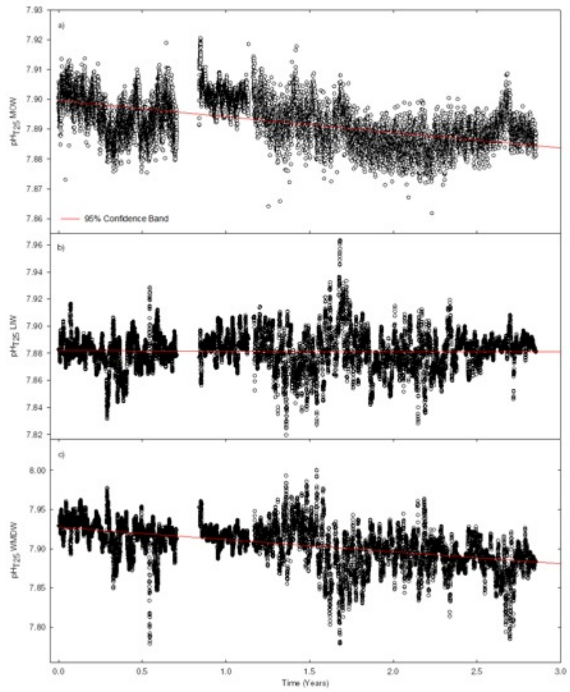

Fig. 3. *Linear fitting of pH with time of the MOW and its forming water masses: a) MOW, b) LIW and c) WMDW.*

4. Conclusions/Discussion

Our work allows to reproduce pH variability in the MOW, as modelled data faithfully mimic the *in situ* measurements recorded in the area. The pH value in the Mediterranean tongue is however, the result of the combination of the pH characterizing the two water masses that form the MOW, the WMDW and the LIW, which could be split by an OMP analysis. The LIW mostly contributed to the flow but exhibited lower and stable pH values, reflecting the effect of remineralization processes occurring during its transit time from the Levantine Basin to the Strait and the length of such period age (in the order of 100 years), as this intermediate water mass has not been affected by the present atmospheric CO_2 concentrations. Therefore, LIW becomes slightly (and slowly) more acidic every year. Conversely, the WMDW exhibited higher pH values, which also varied remarkably during the winter months, as a result of the water ventilation pattern of this water mass. The more recently produced WMDW shows a marked pCO_2 rise (not shown) and a considerable pH decreasing trend. This is the consequence of the impact of a higher atmospheric CO_2 concentration when this water mass is formed along with the faster penetration of the gas in the water column due to its high alkalinity (Copin-Montégut and Bégovic, 2002). Also, the organic matter that reaches the bottom layer after deep water formation events, is rich in labile and easily oxidizable material, and its decomposition leads to significant CO_2 release. Thus WMDW indeed supports high rates of organic carbon degradation mainly due to the organic matter that was transported during the formation event. Our data indicate that there is a significant rate of pH decline in the MOW with time, which is sensitive to both biological processes at the basin level and physical mechanisms occurring at regional scale (Flecha et al., 2015).

5. Acknowledgements

Funding for this work was provided by the European projects CARBOCHANGE (FP7-264879) and PERSEUS (FP7-287600), by the Spanish Ministry of Economy and Competitiveness (CTM2010-

21229) and by SOCIB. The cooperation of the captains and crews of the research vessels "SOCIB", "Sarmiento de Gamboa", "Angeles Alvariño", "Cornide de Saavedra" and "Ramon Margalef" is highly appreciated. SF was supported by a JAE PREDOCTORAL scholarship from the Spanish Ministry for Economy and Competitiveness co-funded by the European Commission (European Social Fund, ESF2007-2013).

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Acidification of the North Aegean Sea from anthropogenic carbon

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Abstract

High anthropogenic CO_2 (C_{ANT}) content was detected at intermediate and deep layers of the North Aegean reflecting the effective transportation of the absorbed atmospheric CO_2 at the surface to the deeper waters via the dense water formation episodes. The layer occupied by modified waters of Levantine origin is more affected by the penetration of C_{ANT} than the North Aegean Deep Water mass that fills the deep part of the basin, indicating the influence of the intensity of dense water formation events and of the different properties and pathways followed by the cascading dense waters. The invasion of C_{ANT} has lead to more acidic conditions and to lower saturation degree of calcium carbonate in relation to the preindustrial era.

Keywords: Anthropogenic CO_2, acidification, carbonate system, Aegean Sea, Mediterranean Sea

1. Introduction

Ocean uptake of anthropogenic CO_2 alters ocean chemistry, leading to more acidic conditions and lower chemical saturation states (Ω) for calcium carbonate minerals, a process commonly termed "ocean acidification" (e.g. Caldeira & Wickett 2005). Marginal seas as the Mediterranean Sea do play an important role in anthropogenic carbon uptake and storage (Lee et al., 2011). The Aegean Sea is one of the few places in the Mediterranean Sea where dense water mass formation takes place having thus the ability to transfer anthropogenic CO_2 (C_{ANT}) into the deep layers. Additionally in its north-northeastern part it receives exceptionally high alkalinity inputs by riverine waters and low salinity waters of Black Sea origin amplifying, through the simple acid-base reaction, the effective atmospheric CO_2 absorption in its surface layer.

Anthropogenic CO_2 cannot be chemically discriminated from the bulk of dissolved inorganic carbon (C_T) and measured directly, thus several approaches for its indirect estimation, based on different concepts and assumptions have been developed. In the present work the simple and accurate TrOCA (Tracer combining Oxygen, inorganic Carbon and total Alkalinity) approach (Touratier and Goyet, 2004; Touratier et al., 2007) is chosen to estimate the C_{ANT}. Nevertheless the comparison of TrOCA approach with other methods has testified that it provides a reasonable overestimation of C_{ANT} but similar spatial variations (Hassoun et al., 2015 and references therein).

Although the considerable influence of the Aegean on the Mediterranean CO_2 system distribution and dynamics, there is a sparseness of reliable measurements of the carbonate system parameters. In the frame of Perseus-AEGEX experiment, for the first time a total of eight stations have been sampled for the determination of A_T and C_T allowing the estimation of anthropogenic CO_2 penetration and acidification levels in the North Aegean Sea and the assessment of the importance of deep water formation process in the CO_2 penetration in the Aegean Sea.

2. Materials and methods

Seawater sampling for the determination of A_T and C_T was performed during October 2013 onboard the R/V Aegaeo, at eight stations in the North Aegean Sea on an N-S transect almost along 25.28E crossing the North Lemnos basin in the frame of the Perseus-AEGEX experiment (Fig. 1).

A_T and C_T measurements were preformed simultaneously using the potentiometric acid titration method in a closed cell (DOE, 1994). The accuracy of the A_T and C_T was assessed by measurements of certified reference material (CRM, Batch #131, A.G. Dickson, Scripps, CA, USA).
pH at the in situ temperature, salinity and pressure conditions was calculated at the seawater scale from A_T and C_T using the CO2SYS program (Pierrot et al., 2006) and following the same parameterization as in (Hassoun et al., 2015).

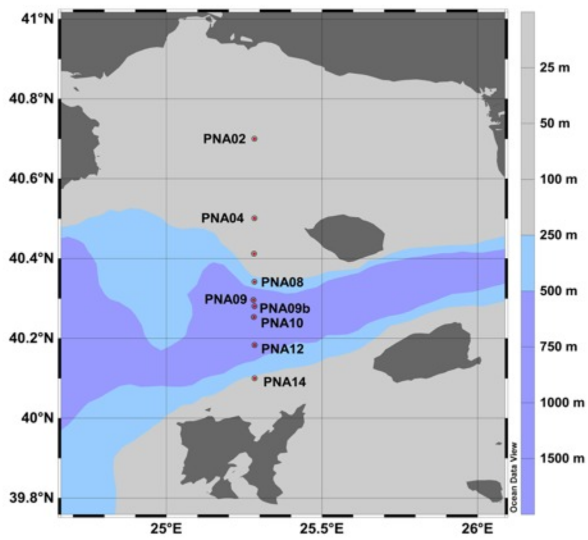


Fig. 1. *Map of the Perseus AEGEX cruise in the North Aegean Sea during October 2013. Nominated stations correspond to those sampled for C_T and A_T determination.*

Similarly the saturation degree of calcite (ΩCa) and aragonite (ΩAr) were also computed. The estimation of C_{ANT} (μmol/kg) was performed with the TrOCA approach (Touratier and Goyet, 2004; Touratier et al., 2007) using potential temperature, oxygen, C_T and A_T data. Then the pre-industrial pH was estimated from the measured C_T values corrected for the C_{ANT} contribution and the original A_T data. The acidification level (ΔpH) is computed from the difference between the 2013 pH and the pre-industrial pH values: $\Delta pH = pH_{2013} - pH_{pre\text{-}industrial}$. Similarly the variations of calcite and aragonite saturation state between the pre-industrial period and 2013 ($\Delta\Omega Ca = \Omega Ca_{2013} - \Omega Ca_{preind.}$ and $\Delta\Omega Ar = \Omega Ar_{2013} - \Omega Ar_{preind.}$) were calculated.

3. Results & Discussion

The estimates of C_{ANT} at the surface and within the upper mixed layer are not reliable, since the TrOCA approach is based on the initial assumptions of constant elemental ratios and of a closed system. When eliminating all estimates corresponding to depths less than 300m the C_{ANT} concentrations ranged between 50.3 (station PNA12-776m) and 79.2 (station PNA10-700m), having an average value 67.58.94 μmol/kg, very similar to the mean C_{ANT} concentrations observed recently at intermediate and deep water masses of the Eastern Mediterranean (Hassoun et al., 2015).

The intermediate layer of the stations situated in the middle and the northern part of Lemnos basin is more invaded by anthropogenic CO_2 (Fig. 2). The C_{ANT} content of the North Aegean Deep Water (NAgDW) mass (σθ>29.3) that fills the deep part of the basin is 66.3±9.2 μmol/kg, while the layer occupied by the Modified Levantine Intermediate Water (MLIW; depth>300m; 28.9<σθ<29.2) is more affected by the penetration of anthropogenic CO_2 and is characterised by higher average C_{ANT} concentration (74.4±4.9 μmol/kg). It would be considered that during winter 2012 surface waters of Samothraki plateau that were directly in contact with the atmosphere, thus being heavily anthropogenic CO_2-loaded, became cold and dense enough, cascaded downslope following possibly different pathways (namely submarine canyons), until they reached their equilibrium depth and transferred there high C_{ANT} loads.

The open ocean C_{ANT} concentrations are much lower than those estimated for the North Aegean, and in general for the Mediterranean Sea. The main reason of the higher uptake and vertical penetration of CO_2 in relation to the open ocean is the regular ventilation of the water column during dense water formation episodes combined with surface waters having a relatively low Revelle factor. In the present-day ocean the Revelle factor, varies between 8 and 13 (Sabine et al., 2004); the lower the Revelle factor, the larger the buffer capacity of seawater. The surface waters of the North Aegean characterized by Revelle factor values close to 9.5, it is evident that are prone to absorb and have a relatively high ability to store C_{ANT}.

Despite the high anthropogenic CO_2 content, the pH throughout the water column of the North Aegean lies above 8.0 and ranges between 8.085 at 1500m of station PNA10, and 8.223 at 100m of PNA14. In general within the upper part of the water column the highest pH values have been calculated since the CO_2 uptake by phytoplankton increases seawater pH and shifts the dissolved inorganic carbon equilibrium toward carbonate ions. The intermediate and deep waters of the southern edge of the basin are less acidic than those of the northern part in proportion to the C_{ANT} penetration (Fig. 2.)

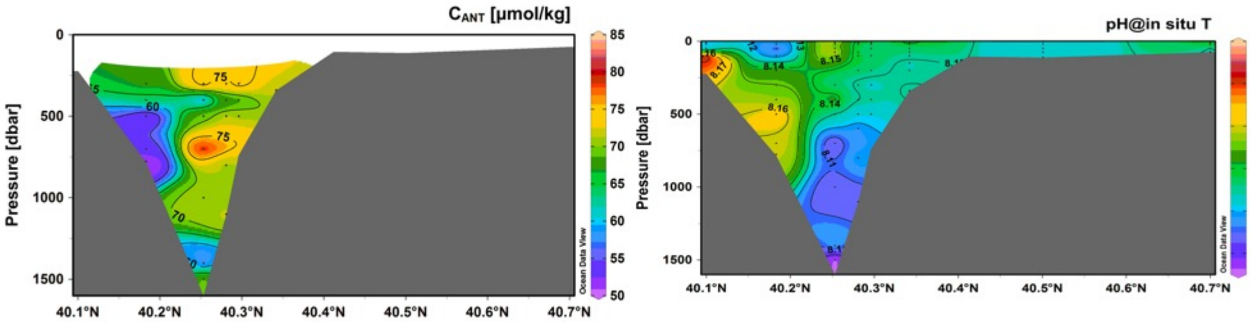


Fig. 2. *Vertical distribution of C_{ANT} and pH at in situ temperature along the transect of AEGEX cruise.*

The estimates of acidification ($\Delta pH = pH_{2013} - pH_{pre\text{-}industrial}$) show that during October 2013 the North Aegean Sea waters below 300m depth are already acidified (Fig. 3). A pH decrease ranging between -0.071 and -0.117 pH unit is noted, being higher in the middle and northern part of Lemnos basin following quite similar pattern with C_{ANT}. Higher ΔpH estimates were obtained at the MLIW layer (-0.106±0.009) than at the North Aegean Deep Waters (-0.095±0.015). In addition the relatively high standard deviation indicates the heterogeneity of the waters occupying the deep part of Lemnos basin as a result of the minor dense water formation event that occurred in 2012. The ΔpH values fall into the ranges reported for the intermediate and deep waters of the Mediterranean basin (Hassoun et al., 2015 and references therein).

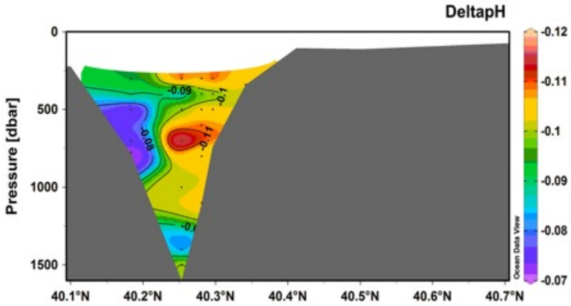
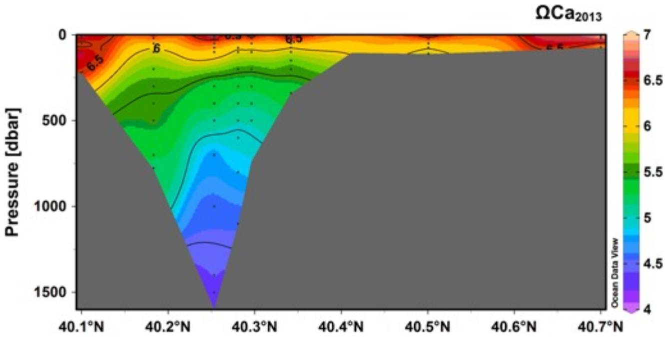


Fig. 3. *Vertical distribution of acidification level (ΔpH) along the transect of AEGEX cruise.*

The North Aegean Sea is supersaturated (Ω>>1) with respect to both calcium carbonate minerals (calcite and aragonite) throughout the whole water column; the saturation state of calcite ($ΩCa_{2013}$) ranges between 4.14 and 7.64 (Fig. 4) and that of aragonite ($ΩAr_{2013}$) between 2.71 and 4.98 (not shown – exhibits identical distribution pattern as $ΩCa_{2013}$). It is evident that the upper layers are characterized by higher Ω values than the deeper ones (Fig. 4) reflecting the elevated carbonate ions content of the highly alkaline waters occupying the upper layer as well as the effect of hydrostatic pressure and lower temperature on the solubility of the calcium carbonate.



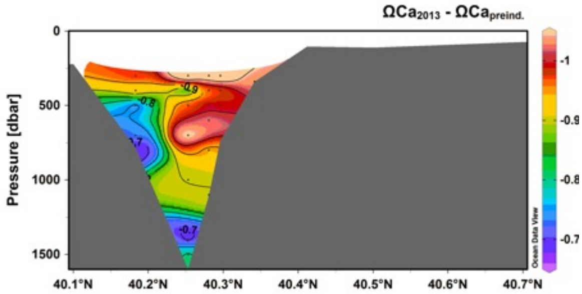


Fig. 4. *Vertical distribution of calcite saturation state ($ΩCa_{2013}$) and variation of calcite saturation between 2013 and the pre-industrial era ($ΩCa_{2013} – ΩCa_{preind.}$) along the transect of AEGEX cruise.*

The high degree of saturation found in the North Aegean is in agreement with previous studies in the Mediterranean (Hassoun et al., 2015 and references therein). However the Ω values calculated in the frame of this study are higher than those referred for the Aegean waters and in particular for the upper 150m of the water column, by Álvarez et al. (2014), being probably attributed to the higher contribution of highly alkaline waters from the Black Sea and the local rivers. The calcite and aragonite saturation state, in the North Aegean Sea exhibit a strong decrease in relation to the pre-industrial era conditions varying from -0.67 to -1.13 for ΔΩCa ($ΩCa_{2013} – ΩCa_{preind.}$; Fig. 4) and from -0.44 to -0.73 for ΔΩAr ($ΩAr_{2013} – ΩAr_{preind.}$; not shown – exhibits identical distribution pattern as ΔΩCa), reflecting the aggravated effect of the excessive anthropogenic CO_2 penetration, and thus of the ocean acidification on the calcium carbonate states.

4. Conclusions

The intermediate (>300m) and deep layers of the North Aegean are invaded by anthropogenic CO_2; the layer occupied by the MLIW is more affected by the penetration of anthropogenic CO_2 and is characterised by higher average C_{ANT} concentration (74.4±4.9 μmol/kg) than the NAgDW mass that fills the deep part of the basin (C_{ANT} = 66.3±9.2 μmol/kg). This fact is attributed to the intensity of dense water formation events and to the different properties and pathways followed by the cascading dense waters. The invasion of C_{ANT} has lead to more acidic conditions and to lower saturation degree of calcium carbonate in relation to the preindustrial era (ΔpH: -0.071 – -0.117 pH unit; ΔΩCa: -0.67 – -1.13; ΔΩAr: -0.44 – -0.73). However calcium carbonate ions depletion is not considered an anticipated problem at least in the near future, since the N. Aegean remains highly supersaturated in both calcite (ΩCa ~ 4.14-7.64) and aragonite (ΩAr ~ 2.71-4.98).

5. Acknowledgements

This research has been partially supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Circulation, ecosystem dynamics and climate sensitiveness in the Central Mediterranean region.

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Abstract
Phytoplankton dynamics is influenced by the Ionian Sea circulation, that is linked, through the mechanism called BiOS, to the thermohaline properties of the dense water produced in the Adriatic Sea. After the premature reversal of the Ionian circulation in 2012, it is evident that the entire Adriatic-Ionian system is highly sensitive to atmospheric forcing in the Adriatic. This suggest a new vision of the possible impact of climate change on physical and biological processes in the Central Mediterranean. Satellite Chl-a phenology and sea level topography are proven to be useful tool for assessing the Central Mediterranean environmental state.
Keywords: BiOS, bloom, chlorophyll-a, Ionian Sea, ADT.

1. Introduction

The dense water formation process in the South Adriatic and the circulation of the North Ionian Gyre (NIG) interact through a cyclostationary negative feedback mechanism called Bimodal Oscillating System (BiOS). The BiOS mechanism is briefly summarized here. During the last 30 years it has been observed that the upper layer circulation in the northern Ionian reversed on decadal time scales, from anticyclonic to cyclonic and vice versa. Reversals result in two different Atlantic Water (AW) pathways in the Ionian. The anticyclonic Ionian circulation mode brings fresher AW into the northern Ionian interior, diminishing the salt content (Fig. 1, left). Consequently, the result of this circulation pattern is the inflow of relatively fresh Ionian waters into the Adriatic, increasing the buoyancy of the water column and obstructing the vertical convection. At the same time the anticyclonic mode weakens the spreading of the AW into the Levantine sub-basin, resulting in an increase in the salinity of the entire Levantine basin, including the Cretan Sea. Therefore, the anticyclonic mode represents a preconditioning mechanism for the dense water formation processes in the Aegean. Conversely, the cyclonic Ionian circulation mode (Fig. 1, right) favours the spreading of the Levantine high-salinity waters in the northern Ionian interior and consequently into the South Adriatic. Thus, as opposed to the Ionian anticyclonic circulation, the Adriatic is more prone to vertical convection and dense water formation. AW, on the other hand, reaches the Cretan Passage via the shortest pathway, diluting the upper layer of the Levantine and Cretan Sea to a greater extent than in the anticyclonic mode. The cyclical fluctuation in salinity of the Adriatic water determines the concomitant changes in the density of the Adriatic Dense Water flowing in the Ionian Sea through the Strait of Otranto. The resulting changes of the horizontal density gradient in the deep Ionian basin is the main responsible of the upper-layer circulation reversals.

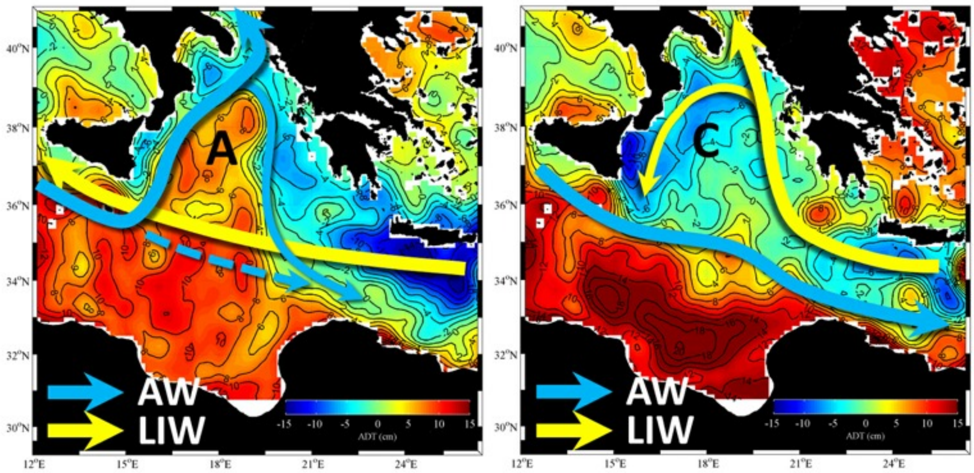

Fig. 1 *Simplified pathway of the major water masses according to the BiOS phases: A, anticyclonic; C, cyclonic. The maps on the background represent the annual average of Absolute Dynamic Topography (cm) in 1995 (left) and 1999 (right).*

Here, we will focus our attention to two importan aspects of the BiOS: (i) the impact of anomalous heat fluxes following the extremely severe winter 2012 in the Adriatic Sea on the dynamics of the NIG, and (ii) the effects of the NIG circulation on the phytoplankton bloom dynamics through the analysis of satellite chlorophyll phenological metrics.

2. Materials and methods

Annual average ADT were calculated from the altimetry data gridded products from AVISO (http://www.aviso.altimetry.fr/fileadmin/documents/data/tools/hdbk_duacs.pdf). For more detailed information, refer to Gacic et al. (2014). Daily chlorophyll-*a* concentration ([Chl-a]) products, with a 4-km resolution, delivered by the Ocean Colour Climate Change Initiative (OC_CCI) project version 1.0 (http://www.esa-oceancolour-cci.org/) were used to analyse phenological metrics. The OC_CCI dataset covered the period September 1997 to July 2012.

3. Results

Recently, two opposite winter conditions occurred in the area: in 2012, winter was very severe and generated exceptional dense waters, more than 1.030 kg/m^3 in the northern basin, the value reached only twice in the last 100 years (Mihanovic et al., 2013). The heat fluxes in the convection area in the South Adriatic Pit were also very strong: six episodes with surface heat losses stronger than 400 Wm^{-2} occurred in January–February 2012 (Gacic et al., 2014). Conversely, winter 2013 and 2014 were very mild and the lack of new dense water production was particularly noticeable. Winter 2012 case study (Gacic et al., 2014) has been carried out in order to assess the sensitiveness of the BiOS on the climatic forcing. Due to the very dense water flowed into the Ionian in 2012 from the Otranto Strait, the NIG circulation prematurely reversed to anticyclone (Fig. 2). The reversal of NIG circulation is evident by looking at the annual average Absolute Dynamic Topography (ADT) distributions in the Central Mediterranean. As a thumb rule, the anticyclonic circulation can be inferred by the protrusion of the AW meander (yellow-red area) into the northern Ionian. In Fig. 2, the AW meander is clearly visible in the sequence from 2006 to 2010. In 2011, the anticyclone to cyclone reversal occurred, as evidenced by the southward retreat of the AW meander substituted by a large light blue area. The cyclonic pattern was interrupted in 2012, with the AW meander invading again the northern Ionian. In 2013, the cyclonic circulation re-established, and it reinforced in 2014.Cyclonic (anticyclonic) circulation causes uplift (downlift) of isopycnals, and the consequent displacement of nitracline. The effects of NIG circulation on the vertical displacement of the nitracline was already highlighted by Civitarese et al. (2010), who found the depth of nitrate conc. of 3 μM ranging from 300 m (anticyclonic) to less than 100 m (cyclonic).

Analysis of climatological (1998-2011, including both cyclonic and anticyclonic periods) seasonal cycles of surface satellite [Chl-*a*] along 18°E in the Ionian Sea shows the results depicted on Fig. 3. Results can be summarized as follows: during the cyclonic regime, south of 35°N, [Chl-*a*] increased from Oct. to Jan., and decreased from Feb. to May; between 36°N and 37°N, the behaviour of chl-*a* displayed a plateau between Dec. and March; north of 38°N, the winter plateau was followed by a spring peak. South of 37°N, chl-*a* bloom initiated in Dec. whereas north of 37°N, bloom started in January or February. Two different ecosystem regimes seem to characterize the Ionian Sea when NIG is cyclonic. However, during the anticyclonic regime, the spring peak, north to 38°N, disappeared and wherever along the 18°E meridian, main chl-*a* bloom initiates between late November and mid-December, suggesting that the whole Ionian Sea (north and south) underwent same phytoplankton dynamic.

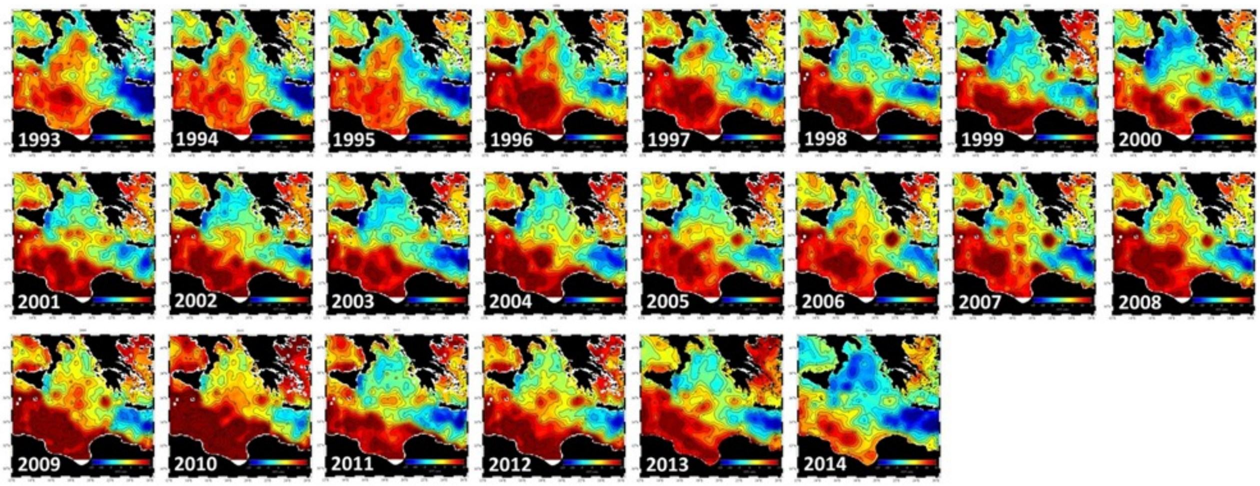

Fig. 2 *Annual average ADT distributions in the Central Mediterranean.*

4. Conclusions/Discussion

Winter 2012 case study highlighted the sensitiveness of the BiOS mechanism to atmospheric forcing in the South Adriatic. In addition, the study definitely proved that the main agent driving the NIG circulation is the internal deep horizontal density gradient between the center and the border of the Ionian Sea. These conclusions suggest that future climate variability, as for example the increase of cold air outbreaks foreseen for the 21st century in the Mediterranean area, will have important role in changing the BiOS cycles and the intensity of the NIG circulation.

From the [Chl-*a*] seasonal cycles, in the Ionian Sea two different ecosystem dynamics co-exist. In fact, during the cyclonic regime, the system gradually passes from a subtropical-like cycle south of 35°N, characterized by a bell-shaped [Chl-*a*] behaviour, to a spring-peak cycle north of 38°N, where the spring bloom is clearly evidenced by the peak of [Chl-*a*] occurring in the second half of March. This particular dynamic, characterized by a moderate spring bloom, is favored by the cyclonic circulation and is absent when NIG circulation is anticyclonic. Cyclonic circulation make nutricline shallower (Civitarese et al., 2010), enhancing the surface nutrients supply at the center of the gyre, thus preconditioning the phytoplankton spring bloom. This never happens in the southern part, where AW presence and anticyclonic circulation prevail.

Here, we have shown that (i) NIG circulation, driven by the BiOS mechanism, is very sensitive to the climatic conditions in the area of dense water formation (South Adriatic), and that (ii) blooms development (and new production) are facilitated when the NIG circulation is cyclonic.

If, as stressed by Crise et al. (2015), the European Marine Strategy Framework Directive represents a new challenge in the environmental protection strategies for the open seas, more detailed investigations and the adoption of proper spatial and time scales should be implemented in monitoring programs for the next future in order to account for the natural and human-induced variability in sub·

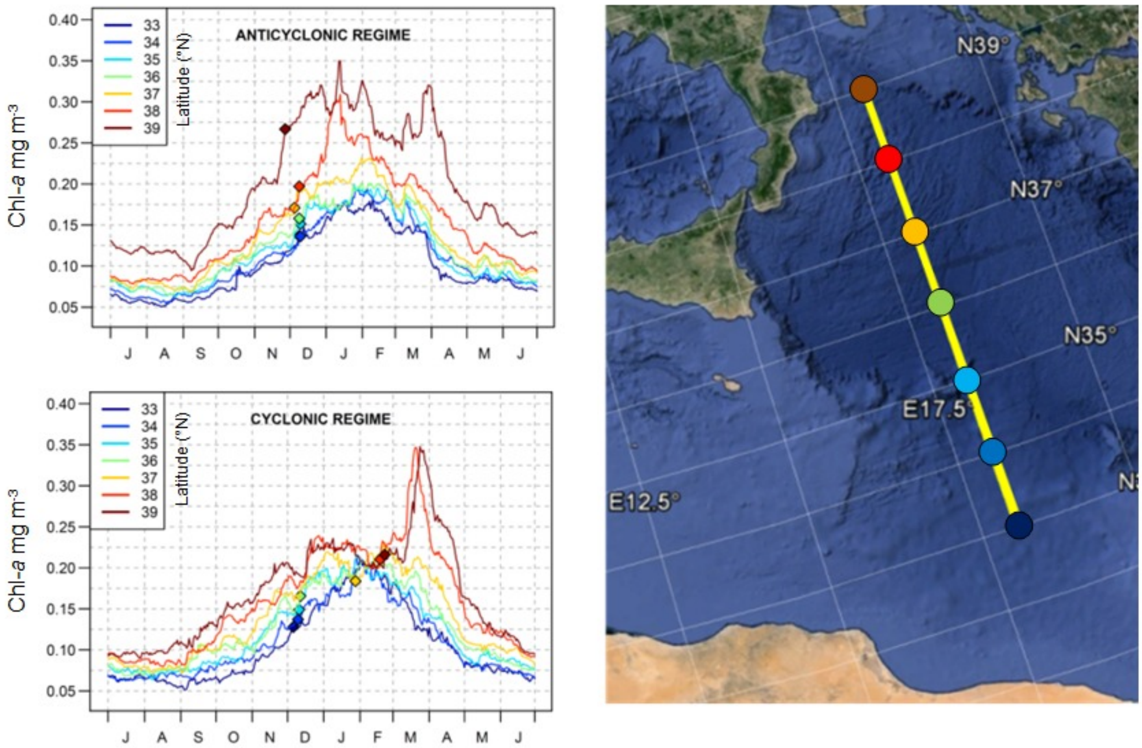

Fig. 3 *Climatological seasonal cycles of satellite chlorohyll-a concentration along 18°E in the Ionian Sea during the cyclonic regime (1999-2005) and during the anticyclonic regime (2007-2011). Diamonds on time-series represent the estimated dates for main [Chl-a] blooms.*

5. Acknowledgements

This work has been partially funded by the EU PERSEUS Project, and by the Italian Ministry of Education, University and Research (MIUR) under the RITMARE Project.

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Scientific Conference
“Integrated Marine Research in the Mediterranean and the Black Sea”

Back to basics: Measuring IOPs in the Aegean Sea to support chlorophyll-α retrieval from ocean colour

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Abstract
The complex optical properties of NE Aegean Sea particles were studied in the framework of Perseus and AegeanMarTech projects. Inherent optical properties (IOPs; beam attenuation, optical backscattering, fluorescence) and discrete bottle data (PMC, POC, TChl-α) were measured during October 2013, March and July 2014. Black Sea water (BSW) enters into the Aegean Sea from the Dardanelles and disperses to the west-northwest, as traced by characteristic salinity minima. The core of the BSW to the east of Limnos Island was occasionally particle-enriched, showing maxima in beam c_p, b_{bp}, fluorescence, D50, PMC, POC, and TChl-α, the latter, however, detected primarily at sub-surface layers. Based on the estimated bulk particulate index of refraction a 3-layer structure was identified, revealing a complex particle composition of variable mixtures of terrigenous and biogenic particles.
Keywords: attenuation, scattering, particles, remote sensing, Descriptor

1. Introduction

It is well-acknowledged that remote sensing techniques are reliable tools to complement the scarcity of oceanographic data in the open sea, as long as systematic calibration and validation exercises are in place, and this holds particularly true for the Descriptor 5-Eutrophication of the MSFD (Palialexis et al, 2014). However, regional seas such as the Eastern Mediterranean, with extremely transparent waters of various origins introduce difficulties in the estimation of chlorophyll-*α* from satellites, often leading to several-fold overestimation, regardless of the operational or regional algorithm applied (Drakopoulos et al., 2015). In the framework of the AEGEX experiment, the present work adds basic knowledge on the optical properties of the Aegean Sea waters in respect to their inherent optical properties complemented with bulk biogeochemical data, thus contributing towards a better assessment of remote sensing derived chlorophyll-*α*.

2. Materials and methods

Perseus AEGEX cruise took place between 4 and 9 October 2013 and was followed by the first AegeanMarTech cruise (1AMT, 9-12 October 2013), aboard the R/V Aegaeo. The second AegeanMarTech cruise (2AMT) was conducted between 19 and 26 March 2014 and the last

AegeanMarTech cruise (3AMT) was conducted from 13 to 20 July 2014. A total of 46 stations were occupied, at water depths varying between 60 and 1596 m (Fig. 1). Conductivity-temperature-depth (CTD) profiles were collected at all stations, accompanied by light transmission (WET Labs C-Star, 660 nm), chlorophyll fluorescence (Chelsea AQUA*tracka* III; excitation: 430 nm, emission: 685 nm), particle volume concentration and particle size distributions (LISST-Deep) (for details see Karageorgis et al., 2012). In addition, the total backscattering coefficient b_b was measured by a WET Labs ECO-BBFL Measurement Sensor at 660 nm. As only c_p and b_{bp} measured at 660 nm are used here, the wavelength is omitted in what follows.

Water samples from standard depths were filtered to determine the concentrations of particulate matter (PMC), particulate organic carbon (POC) and total chlorophyll-*α* (TChl-*α*) (for details see Karageorgis et al., 2014). Continuous total chlorophyll-*α* profiles were obtained by linear regression between CTD fluorescence readings and bottle Chl-*α* data (HPLC method).

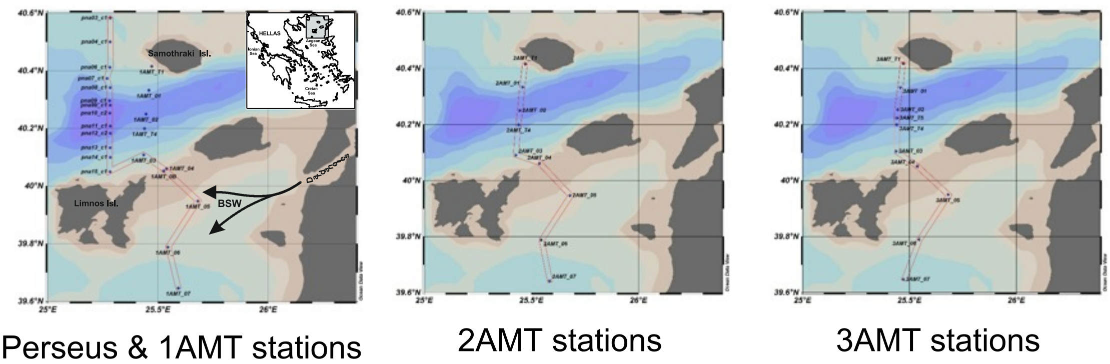


Fig. 1 *Study area map and sampling stations in the NE Aegean Sea. Red line: transect.*

3. Results

In October and July, temperature at the surface was higher and a strong thermocline was developed, whereas during March surface waters were colder than the underlying saltier Levantine Intermediate Water. Salinity at the surface was largely controlled by the Black Sea Water (BSW) spreading and mixing; the low-salinity layer extended several meters, up to 50-m depth. The core of the BSW was located to the east and north-northeast of Limnos Island, suggesting that, in October and March, the main spreading direction was from the Dardanelles Straits towards the west-northwest, whereas in July to the south-southeast.

Beam c_p in the study area varied between 0.001 and 0.369 m^{-1}, which are very low values, corresponding to Case 1 waters and comparable to the open ocean. Relatively high values were observed at surface waters (0-30 m) and particularly at the core of the BSW, followed by higher values near the seabed, around 100-m depth. The latter pattern is attributed to sediment resuspension due to current activity and was consistent throughout the cruises.

Overall, c_p and b_{bp} were positively correlated suggesting that possibly the NE Aegean Sea waters are more like Case 1, thus showing open-sea characteristics, where scattering is phytoplankton-dominated. On the contrary, in resuspension zones lithogenic particles were more abundant hence waters could be locally characterized as Case 2. However, both variables were uncorrelated to TChl-*α* indicating that other factors add to breaking up a quasi-linear relationship observed in the open ocean (Dall' Olmo et al., 2009). The main factor is most probably the variable composition of suspended particles, which have mean %POC >40% (%POC = 100 × POC/PMC) and variable particle-size distributions (PSD). Particle-size varied between 19 and 199 μm, implying the consistent presence of large aggregates in the water column and increased particle size in the BSW core, although there is some interference due to intense stratification and subsequently schlieren effects (Karageorgis et al., 2014).

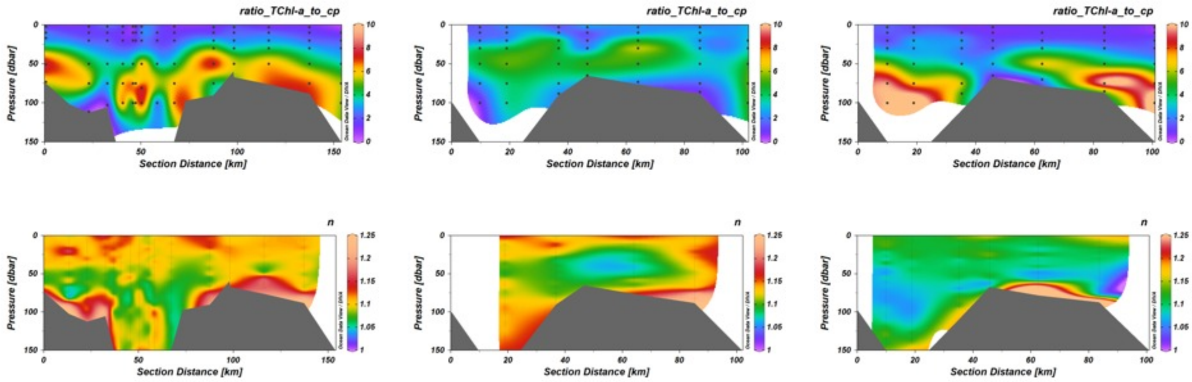
4. Discussion and conclusions

Chlorophyll-*α* is commonly used as a proxy for phytoplankton biomass, whereas the particulate beam attenuation is a reliable proxy for particulate concentration. Thus, the ratio of TChl-α/c_p provides information on the relative contribution of phytoplankton to the total particulate matter concentration. On the other hand, the particulate backscattering ratio, which is the ratio of b_{bp} to b_p, is weakly dependent on concentration and provides information on the particle type, composition and size distribution and can be also used in semi-analytical models for IOPs retrieval. Here we estimate b_p as a function of chlorophyll-*α*: b_p = 0.252 (TChl-α)$^{0.635}$ (Bricaud et al., 1998). Using the b_{bp} to b_p ratio we can then estimate the bulk particulate refractive index n according to the formula: n = 1 + 1 .671 ´ (b_{bp}/b_p)$^{0.582}$ (Twardowski et al., 2001).

The spatial distribution of TChl-α/c_p ratio and the bulk index of refraction n are presented in Fig. 2. Low ratio values appeared mainly at the surface waters throughout the cruises, followed by a subsurface zone with high TChl-α/c_p ratio values, extending occasionally up to the seabed (July 2014). Low ratio values are indicative of low concentrations of phytoplankton and higher indices of refraction corresponding to inorganic mineral particles, whereas high ratio values suggest predominance of phytoplankton with low index of refraction. This pattern is consistent throughout the cruises. Additional supportive information on the particle composition may be drawn from the relationship between the backscattering ratio and the TChl-α/c_p ratio. All data indicate a negative correlation between the two variables, with correlation coefficients r = -0.545, -0.767, and -0.573, for Perseus+1AMT, 2AMT, and 3AMT cruises, respectively. It becomes therefore more consistent that low indices of refraction correspond to high TChl-α/c_p ratios and are indicative of phytoplankton abundance, whereas mineral particles predominate in the opposite case. Our findings are in agreement with Boss et al. (2004), who recorded similar relationships at the Rutgers University Long-term Ecosystem Observatory in the Mid-Atlantic Bight thus providing an independent confirmation of the link between the backscattering ratio and the bulk composition of particles.

During the cruises, the mean value of n varied between 1.094 and 1.123 and falls between phytoplankton- and mineral-dominated waters. Previous studies have shown phytoplankton n to be in the range of 1.01–1.10, and mineral n in the range of 1.14–1.26. Loisel et al. (2007) measured mean n equal to 1.133±0.047 in the eastern English Channel and southern North Sea, whereas Boss et al. (2004) estimated n spanning the full range expected for phytoplankton (n ≈ 1.02 - 1.05) to inorganic particles such as quartz and aragonite (n ≈ 1.15 - 1.24) in the Mid-Atlantic Bight.
According to the spatial distribution of the backscattering ratio and the mean bulk particulate refractive index three water layers can be identified, associated with different particle composition: (a) BSW (~0-30 m) appears to be dominated by material with moderate index of refraction 1.11-1.13; (b) mid-waters (30-65 m) characterized by maximum fluorescence and lower index of refraction (1.09-1.10); and (c) the near-bottom layer which exhibits higher mean n, up to 1.14 (Fig. 2).

Summarizing, we provide new insights on the complex optical properties of the NE Aegean seawater, combining measurements of bulk inherent optical properties and discrete bottle data. The present work helps to better understand both the IOPs and the water-leaving radiance, to feed radiative transfer numerical models and ultimately to support the development of more accurate remote sensing products such as the retrieval of chlorophyll concentration from remote sensing ocean color. Moreover, the advent of marine optics offers the opportunity to sample the ocean faster and at a higher resolution than traditional oceanographic methods, both at field and the laboratory, which are often extremely time consuming and costly.



Perseus & 1AMT 2AMT 3AMT

Fig. 2 *Spatial distribution of the* $TChl\text{-}\alpha/c_p$ *ratio and the particulate index of refraction n during the Perseus+1AMT, 2AMT and 3AMT cruises in the NE Aegean Sea.*

5. Acknowledgements

The present study received funding by the project "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP) and the project AEGEANMARTECH (MIS: 383548, Operational Program: "Education and lifelong learning, 2007-2013", Ministry of Education and Religious Affairs).

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Shelf-deep sea exchanges in the Black Sea: an integrated analysis

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Abstract

This study provides an integrated analysis of exchanges of water, salt and heat between the northwestern Black Sea shelf and the deep basin. Three contributing physical mechanisms are quantified, namely: Ekman drift, transport by mesoscale eddies at the edge of the NW Black Sea shelf and non-local cascading assisted by the Rim Current and mesoscale eddies.

Keywords: Ocean modelling, Black Sea, Cascading

1. Introduction

The semi-enclosed nature of the Black Sea together with its unique combination of an extensive shelf area in the North West and the deep central part make it sensitive to natural variations of fluxes, including the fluxes between the biologically productive shelf and predominantly anoxic deep sea. Coastal urbanisation, industrialisation and touristic exploitation resulted in the significant increase of anthropogenic forcings, which have exerted a progressively growing pressure on the Black Sea environment. Exchanges between the shelf and deep sea play an important role in forming the balance of waters, nutrients and pollution within the coastal areas, and hence the level of human-induced eutrophication of coastal waters (MSFD Descriptor 5).

The purpose of this study is to reveal physical mechanisms and quantify shelf-deep sea exchange processes in the NW Black Sea sector using NEMO numerical ocean model. The model is configured and optimized taking into account specific features of the Black Sea, and validated against in-situ and satellite observations. We study effects of frontal mesoscale eddies, Ekman drift and dense water cascading on the exchanges across the Rim Current, a basin-wide shelfbreak gyre which separates shelf areas from the deep basin (see Fig.1).

2. Materials and methods

The study uses NEMO-BLS24 numerical model which is based on the NEMO codebase v3.2.1 with amendments introduced by the UK Met Office.

The NEMO-BLS24 configuration has a horizontal resolution of $^1/_{24}\times{}^1/_{24}$° and a hybrid *s-on-top-of-z* vertical coordinate system with a total of 33 layers. The horizontal viscosity/diffusivity operator is rotated to reduce the contamination of vertical diffusion/viscosity by large values of their horizontal counterparts.The bathymetry is processed from ETOPO5 and capped to 1550m. Atmospheric forcing for the period 1989-2012 is given by the Drakkar Forcing Set v5.2 with NCEP atmospheric forcing also used for 2005. The climatological runoff from 8 major rivers is also included. We run the model individually for 24 calendar years without data assimilation.

For the analysis of propagation of cold waters formed on the NW Black Sea shelf we use a passive tracer method. The tracer is treated as an artificial dye that "stains" a water parcel within the defined area (see Fig.1) as soon as it cooled below a 7°C temperature.

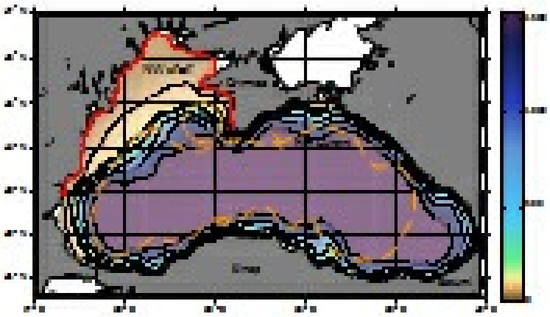

Fig.1 *Map of the Black Sea with the model bathymetry. The NW shelf area is outlined in red. An idealised sketch of the Rim Current and one its quasi-permanent anti-cyclonic eddies (SvEd=Sevastopol Eddy) is overlaid in orange.*

To quantify the shelf–deep sea exchange, the transport of water, salt and heat between the NW shelf and deep-sea regions is calculated across an enclosed boundary (a "fence") approximating the 200 m isobath on the NW shelf plus two short segments connected to the coast. Partial transports are also calculated for the surface layer (top 20 m) and the under-surface layer (from 20 m to the bottom). The 20 m level is approximately equal to the Ekman depth in summer. It is also close to the depth of the biologically active euphotic layer.

3. Results

3.1 Model validation

For validation of the NEMO-BLS24 configuration we present comparisons of the model with satellite-derived sea surface temperature measurements and with ship-derived cross-sections that show the vertical structure.

As an example (see Fig.2) compares satellite-derived SST from Modis Aqua with modelled sea surface temperature in September 2004. The model reproduces well the basin-averaged temperature and the general features and patterns of the temperature distribution.

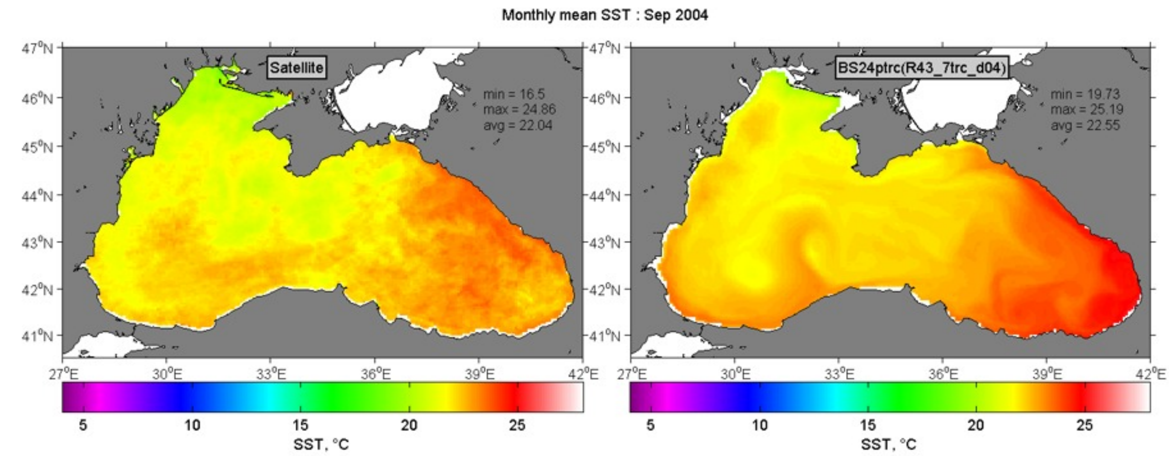

Fig.2 *Comparison of monthly mean SST from Modis Aqua satellite data (left) and model data (right) for September 2004.*

We also compare the model to observations made during Black Sea cruises in 2004, 2007 and 2008. (see Fig.3) represents the model result together with observational data obtained in several cruises by the Russian R/V *Akvanavt* in the northeastern Black Sea in 2008. The model represents well the sea surface temperature, the depth of the upper mixed layer and the depth of the CIL, while overestimating the temperature in the core of the CIL by approx. 0.5 °C.

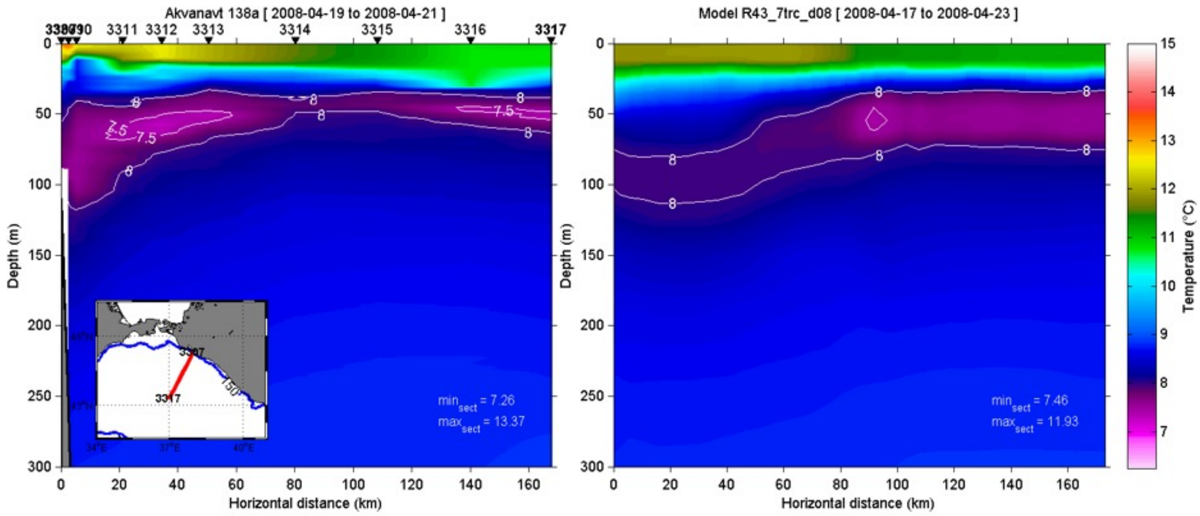

Fig.3 *Comparison of cross-sections from R/V Akvanavt leg 138 in April 2008 (left) with the 7-day average of the model data centred on the same period (right)*

3.2 Cross-shelf transports

Despite the inhibiting action of the steep continental slope (due to potential vorticity constraints), the exchanges across the NW shelf break contribute to fast renewal of shelf waters and to transport of eutrophic surface water masses into the deep-sea region. Two physical processes – a long-lived anticyclonic eddy together with meanders of the Rim Current and wind-driven Ekman transport – are shown to be the major contributing factors to the across-shelf exchange.

3.3 Exchange due to eddies

Numerical simulations for the year 2005 (for which comprehensive remote sensed data is available) shows that a significant cross-shelf transport was generated by a long-lived anticyclonic eddy impinging on the shelf, sometimes assisted by a cyclonic meander of the Rim Current. Over 69 days between April 23 and June 30, 2005, a volume of 2.84×10^{12} m^3 of water (102% of the entire volume of the shelf waters) was transported out of the shelf and a similar amount onto the shelf (see details in Zhou et al. 2014).

3.4 Exchange due to Ekman drift

During the short but intensive wind events of April 15 – 22 and July 1 – 4, 2005, 23% and 16% of shelf waters, were moved into the deep-sea region, respectively (see Error: Reference source not found). Due to the high intensity of cross-shelf exchanges, the average renewal time for the NW shelf in the Black Sea was only 28 days in the summer of 2005 (Zhou et al. 2014).

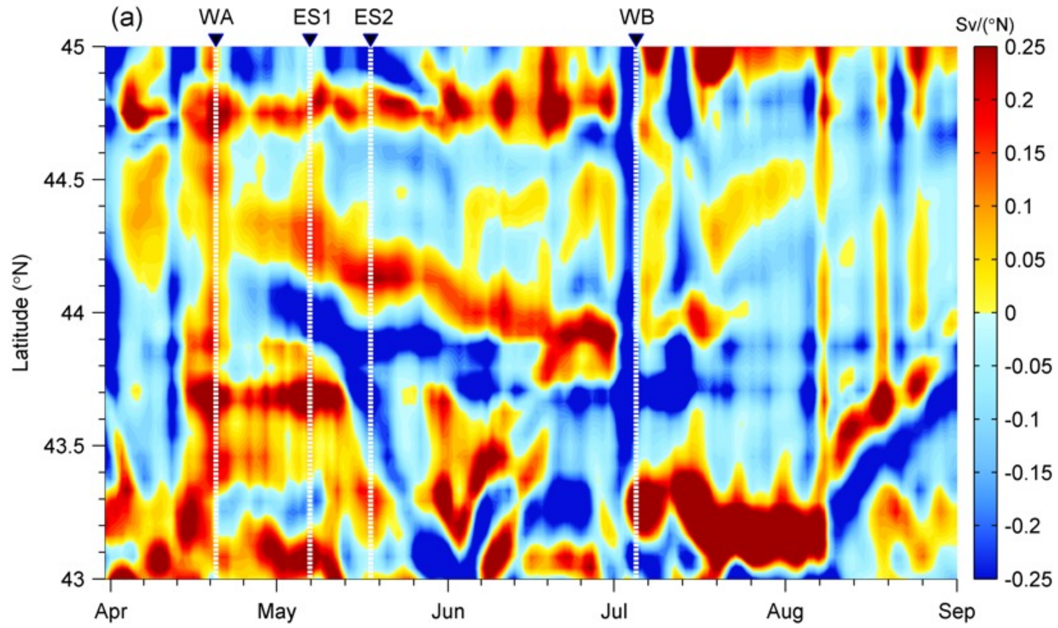

***Fig.4** Hovmöller diagram of the cross-shelf volume transport integrated from the sea surface to 20 m and calculated along the shelf edge as shown in Error: Reference source not found. (positive=offshore transport, units=Sv per 1° latitude)*

3.5 Exchanges due to assisted cascading

Using the model run for 2003 as an example, we examine the fate of the tracer after 5.5 months of model integration. Fig.5 shows maps of tracer concentration (tracking cold shelf water formed at T<7°C) at the 25m and 100m depth levels in mid-May 2003, which gives a good example of the fate of the cold shelf water.

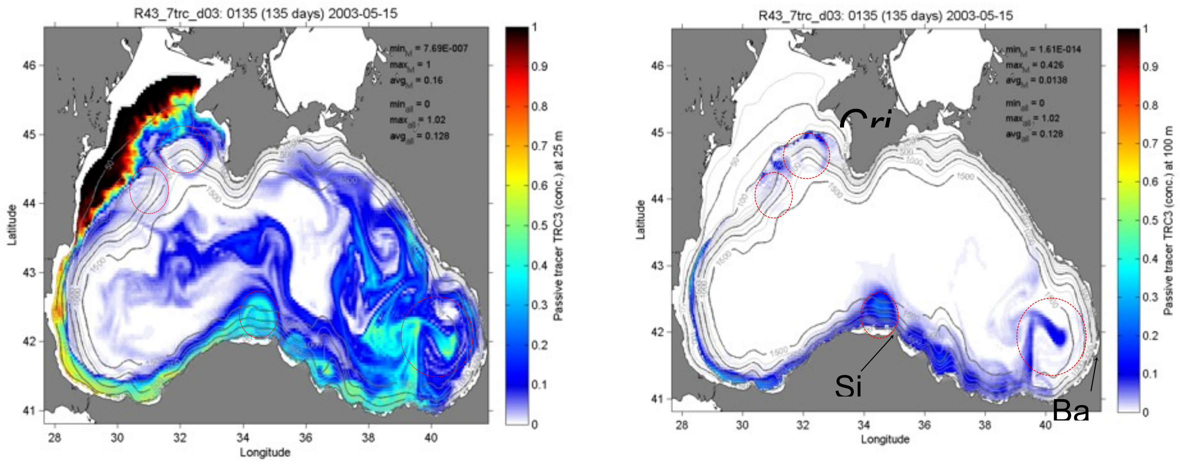

***Fig.5** Tracer concentration at depths 25m (left) and 100m (right) in mid-May 2003.*

At 100m depth we identify four anti-cyclonic eddies: two eddies west of the Crimea peninsula, one north of Sinop and one west of Batumi (Fig.5). These eddies can be seen to assist cascading into the basin interior of cold waters formed on a shallow NW shelf to a depth greater than at which they were originally formed. The important result is that for many of the 24 studied years a significant proportion of dense shelf water does not cascade locally off the NW shelf, but is transported by the

Rim Current over hundreds of kilometres before cascading into the deep basin in the southern and southeastern Black Sea.

4. Conclusions/Discussion

Using a high resolution validated Black Sea ocean model we have been able to identify and quantify 3 mechanisms of shelf-deep sea exchanges in the Black Sea: by mesoscale eddies, by Ekman drift and via non-local eddy-induced cascading of dense water. The latter is a new mechanism, which includes formation of cold dense water on the NW shelf during winter, its transport into the southern and southeastern parts of the Black Sea by the Rim Current in early spring and eddy-assisted cascading onto the deep basin in late spring-early summer.

5. Acknowledgements

This work has been supported by EU PERSEUS and a number of Chinese and Russian national projects.

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Bacterioplankton variability in the Levantine basin (SE Mediterranean Sea), implications on the related Marine Strategy Framework Directive descriptor

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Abstract
In this study we aim to establish a MSFD functional baseline of autotrophic and heterotrophic bacterial abundance and production rates in the open water of the Levantine Basin (LB). For this purpose, the spatiotemporal distribution and production of phytoplankton and heterotrophic bacteria in the surface waters of the LB during five cruises held between 2013- 2015. We emphasize that its seasonal variability and shelf-open sea exchanges should be considered when assessing any anthropogenic modification of its trophic conditions.
Keywords: chlorophyll-a, primary production, bacterial production, phytoplankton, heterotrophic bacteria

1. Introduction

The Levantine basin (LB) in the southeastern Mediterranean Sea (SEMS) is an ultra-oligotrophic marine environment, characterized by low nutrients and low chlorophyll (Chl-a) at its euphotic layer (i.e. Kress et al., 2014). The phytoplankton biomass is mainly comprised of pico-autotrophic cells (Siokou-Frangou et al., 2010), which contribute for approximately 60% of the Chl-a and 65% of the primary annual production (Magazzu and Decembrini, 1995). Heterotrophic bacteria play an important role in the upper layers of the LB and are responsible for a large portion of nutrient recycling in this system (Pulido-Villena et al., 2012).

The MSFD apply an ecosystem-based approach to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status (GES). GES is assessed via a set of 11 descriptors, which collectively represent the state and functioning of the whole system. Descriptor 5 refers to “eutrophication” aspects, not appropriately defined for ultra-oligotrophic basins as the open water in the LB (Crise et al., 2015). While the LB is exposed to atmospheric input of nutrients, which contributes to the trophic budget at basin scale and acts as an additional driver of primary and bacterial production in Low Nutrient Low Chlorophyll areas (Guieu et al., 2014), its seasonal variability and shelf-open sea exchanges should be considered when assessing any anthropogenic modification of its trophic conditions.

In this study, we aim to establish a MSFD functional baseline of autotrophic and heterotrophic bacterial abundance and production rates in the open water of the LB. For this purpose the spatiotemporal distribution and production of phytoplankton and heterotrophic bacteria was monitored in surface waters of the LB during five cruises, between 2013 to 2015.

2. Material and Methods

Water samples were collected on board the *R/V* Shikmona, at stations located in the LB during 2013 to 2015 (Fig. 1). Surface seawater (<15 m) was sampled using Niskin bottles (8 L) mounted on a rosette equipped with a CTD (Seabird 19 Plus) and fluorometer (Turner designs, Cyclops-7) for real-time chlorophyll *a* evaluation.

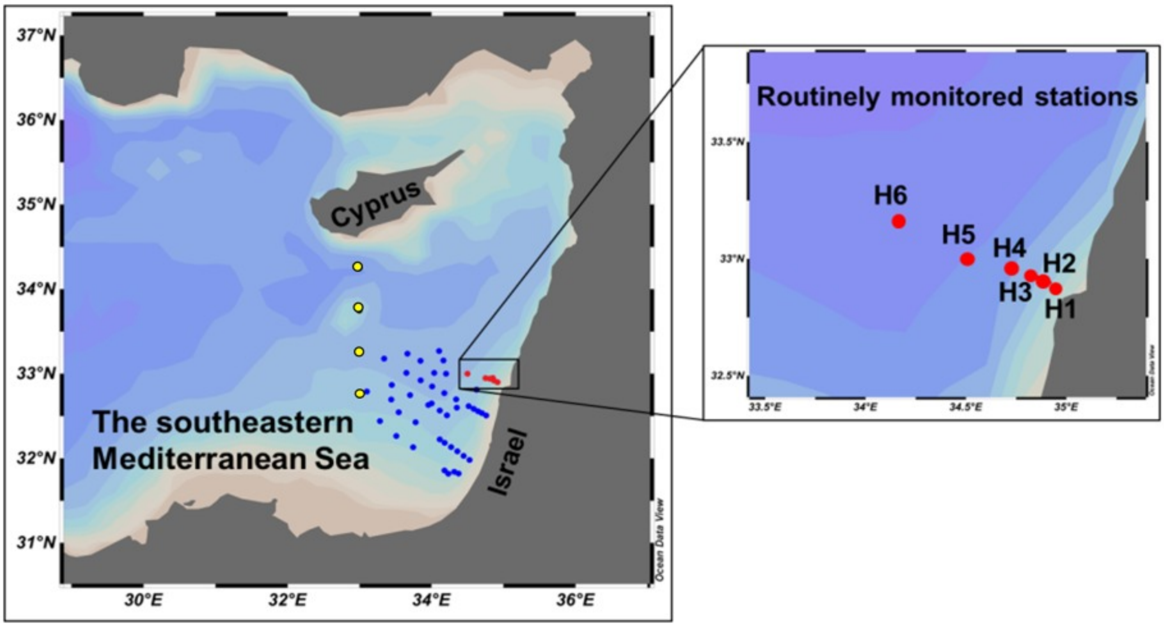

Fig. 1 *Sampling locations in the LB. Red dots show stations sampled during 2013-2015, blue dots indicate additional stations sampled during March 2013, and yellow dots show the locations sampled during December 2013.*

Chlorophyll a (Chl-a)- samples (500 mL) were filtered onto GF/F (Whatman) and extracted in 90% acetone. Concentrations were determined using a Luminescence Trilogy Spectrofluorometer with a 436-nm excitation filter and a 680-nm emission filter (Holm-Hansen et al., 1965).

Cyanobacterial picophytoplankton (i.e. Synechococcus and Prochlorococcus) and heterotrophic bacteria (BA) - samples (1.8 mL) were determined using an Attune® Acoustic Focusing Flow Cytometer (Applied Biosystems) equipped with a syringe-based fluidic system and 488 and 405-nm lasers as described in Bar-Zeev and Rahav, (2015).

Primary and bacterial production- daily primary production was estimated using the ^{14}C incorporation method (Steemann-Nielsen, 1952), while bacterial production (BP) were estimated using the ^{3}H-leucine incorporation method (Simon et al., 1990). Radioactivity was measured using a TRI-CARB 2100 TR (Packard) liquid scintillation counter.

3. Results

The sea surface temperature of the LB exhibited distinct differences between the summer (stratified, ~28-30°C) and winter (mixed, ~17-20 °C) periods. Chl-a levels were overall uniform during the stratified summer (0.06± 0.01 mg m^{-3}) and somewhat higher, yet variable, during wintertime (0.10± 0.05 mg m^{-3}) (Fig. 2A).

Primary production rates were higher in winter (3.60± 1.13 μg C L^{-1} d^{-1}) than in summer (2.72± 0.42μg C L^{-1} d^{-1}) (Fig. 2B). Pico-cyanobacteria dominated the autotrophic community and were mainly composed of *Synechococcus* cells (not shown). The ratio between *Synechococcus* and *Prochlorococcus* was threefold higher during the mixing period than in summer (1.8± 1.0 and 0.6± 1.0 respectively) (Fig.2C).

The abundance of heterotrophic bacteria was highly variable during wintertime (by 2 orders of magnitude, $4.4x10^5$± $3.1x10^5$ cells mL^{-1}) and decreased by ~50% during summer ($2.0x10^5$± $8.3x10^4$ cells mL^{-1}) (Fig.2D). In contrast to bacterial abundance variations, bacterial production was lowest during the mixing period (0.70± 0.65μg C L^{-1} d^{-1}) and twofold higher during the stratified period (1.37± 0.41μg C L^{-1} d^{-1}) (Fig. 2E).

Data from the open sea were compared with data from a coastal site located at the easternmost part of the LB (Raveh et al., 2015), showing significant differences for most variables examined

(Fig. 2, black-dash line). The *Synechococcus:Prochlorococcus* cells number ratio (Fig. 2C), show significant levels in coastal water as compared to open sea, suggesting that it may serves as a fingerprint for coastal water intrusion in the open sea.

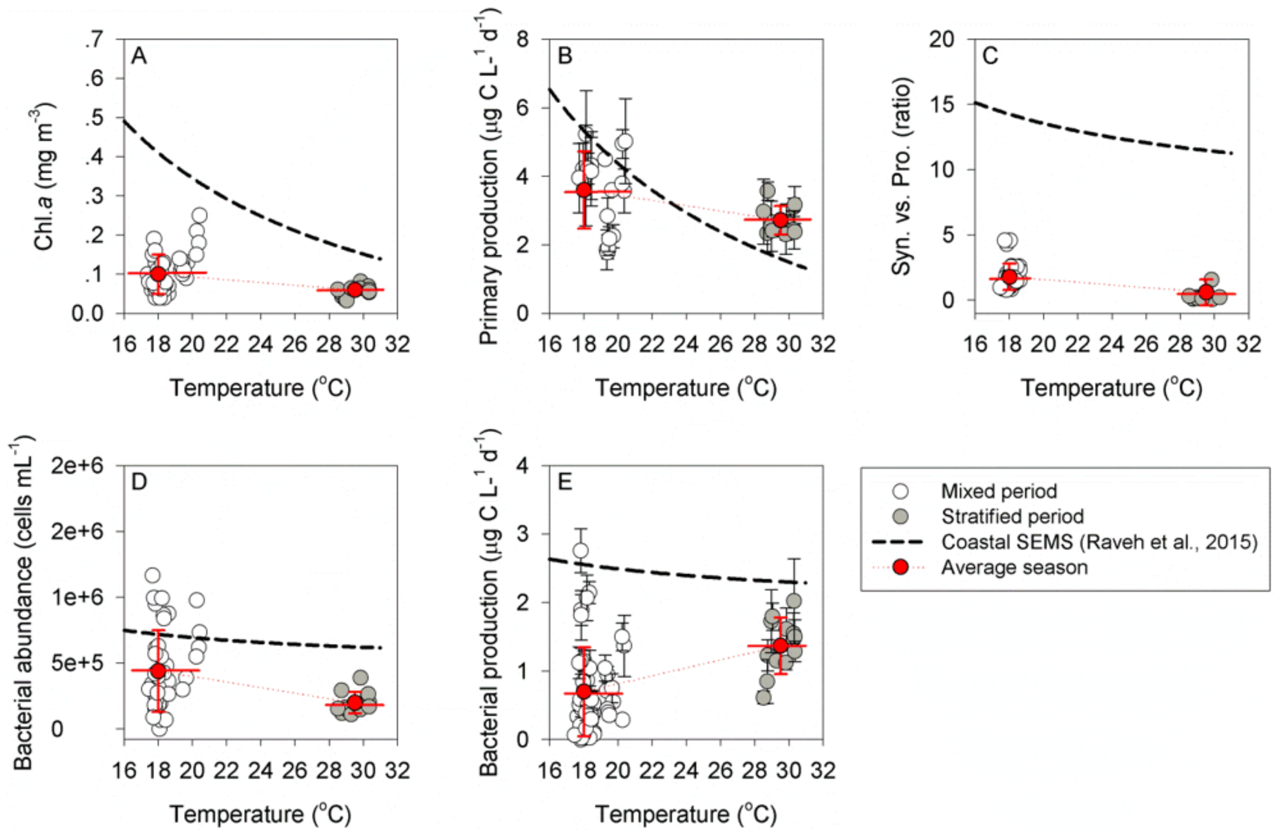

Fig. 2 *The relationship between surface temperature and Chl-a (A), primary productivity (B), Synechococcus/ Prochlorococcus ratio (C) bacterial abundance (D) and bacterial production (E) during the mixing (white), the stratified (gray) period and the average (red) of each period. The black dash line is the correlation found in the coastal SEMS water as described in Raveh et al., (2015).*

4. Discussion

Seasonal dynamics of phytoplankton and bacterial populations are important to the ecology of all aquatic environments, as they are at the bottom of the food web and thus hold a key role in nutrient recycling within the photic layers (Arrigo, 2005).

In the present study, we determined phytoplankton and bacterial properties of the open LB surface waters. High variability in autotrophic, and to some extent heterotrophic, levels were observed during wintertime, while relatively uniform levels were observed during the summer (Fig. 2). The high winter variability is attributed to variations in mixing depths and hence nutrient supply that greatly affects bacterioplankton.

It is suggested here to use the summertime uniform measurements of autotrophic and heterotrophic bacterial abundance and production rates in the open water of the LB as a functional baseline for MSFD criteria. We thus suggest using the average values obtained during the stratified summer period ±2 standard deviations as a baseline for autotrophic and heterotrophic abundance and production.

Furthermore, in several of the bacterioplankton parameters our open-sea levels differed from those found in the coastal zone of the LB (Fig. 2). Events of seawater intrusion of coastal waters into the open sea was previously observed by satellites (Groom et al., 2005), hyperspectral remote sensing surveys (Herut et al.,2002), as well as direct measurements (Efrati et al., 2012). This shelf-open sea exchange was shown to export coastal bacteria and phytoplankton, including potentially toxic cyanobacteria, diatoms, and dinoflagellates. Therefore, following the potential impacts of shelf-open water exchange is essential for the assessment of any baseline modifications of the trophic level in the LB.

5. Acknowledgments

The authors thank the captain and crew of the R/V Shikmona. This study was supported by the PERSEUS project (EC Contract #287600) and by the Israel Ministries of Environmental Protection and National Infrastructures, Energy and Water Resources (grant number 3-11519) to E.R.

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Response of the Black Sea coastal phytoplankton variability during the last decade to climate change and anthropogenic inputs

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Abstract
In this study we address the response of the Black Sea coastal phytoplankton variability during the last decade to climate change and anthropogenic inputs with a focus on Varna Bay region.
Keywords: ecosystem, climate change, indicators

1.Introduction

The coastal area of Varna region is impacted by many interacting stressors due to extensive human activity (industry, tourism and urbanization) and recent global climatic changes (NIAR, 2013). From 1934 to 2001 the population increased fourfold, the population density of Varna (1 350 km-2) far exceeding the country’s coastal average. In 2000-2004 the number of hotels almost doubled, however the infrastructure development tailored to meet the direct tourist demands for leisure and entertainment facilities did not meet environmental protection needs. On the other side during the last decades summer temperatures showed extreme values which have never been measured before, the frequency and intensity of rain events also increased. The climate change is likely to further stress both the coastal ecosystem and resource management. Varna coastal area is among the water bodies along the Bulgarian Black Sea coast reported at risk of not-achieving “good ecological state” by 2020. Marine phytoplankton plays a key role in the lower food web and in the transfer of energy to maintain the function and productivity at the level of a healthy ecosystem. As a fast response component of the marine biota it is a valuable indicator of the ecological/ environmental status of the coastal and marine waters (important element in WFD and component of several MSFD Descriptors). During the last 14 year phytoplankton related indicators showed a very high variability, classifying the ecological status of the coastal area between poor-good (Moncheva et al., 2015) To asses all those changes we utilize observational data and coupled model simulations and provide an extensive analysis on the response of the ecosystem in the Varna coastal region to nutrient loads and climatic changes.

2. Materials and methods

The analysis was based on 13 years spring-summer data sets (2001 - 2014) of meteorological, hydrological, chemical and biological (phytplankton) variables. The assessment of the ecological status was based on classification system of the WFD National monitoring program (Regulation No 4 /14/09/2012).

The hydrodynamical model is based on the three-dimensional GFDL MOM. Solid boundaries are non-slip and insulating for temperature and salinity. Convection is parameterized by convective adjustment that is often used to remove static instabilities. The model has 24 vertical levels; mixing and diffusion in the horizontal are parameterized with biharmonic operators. The vertical diffusion in the model is parameterized as stability dependent. The structure of the biogeochemical model BIOGEN (Lancelot et al., 2002, Staneva et al, 2007)-state variables and processes linking them- is schematically illustrated in Fig. 1. The model describes the cycling of carbon, nitrogen, phosphorus and silicon through aggregated chemical and biological compartments of the planktonic and benthic systems. Each biological component represents a set of different organisms grouped together according to their trophic level and functional ecological behaviour. BIOGEN thus includes 34 state variables assembled in five models. The impact of vertical stratification and forcing with different time scales on the functioning of biological system has been studied by Staneva et al. (1998). The results of coupling between different physical models (mixed layer model, box-like model and 3-D basin-wide general circulation model) and ecosystem model (Lancelot et al., 2002) demonstrate that simulated phytoplankton evolution compares well with the SeaWiFS and CSCZ satellite data. The impact of natural and anthropogenic matter from the land to the coastal environment and identifying limitations on the nutrient capacity of the coastal waters by studying extreme events for the north-western Black Sea have been studied (Staneva at al., 2007 and Kourafalou et al, 2005).

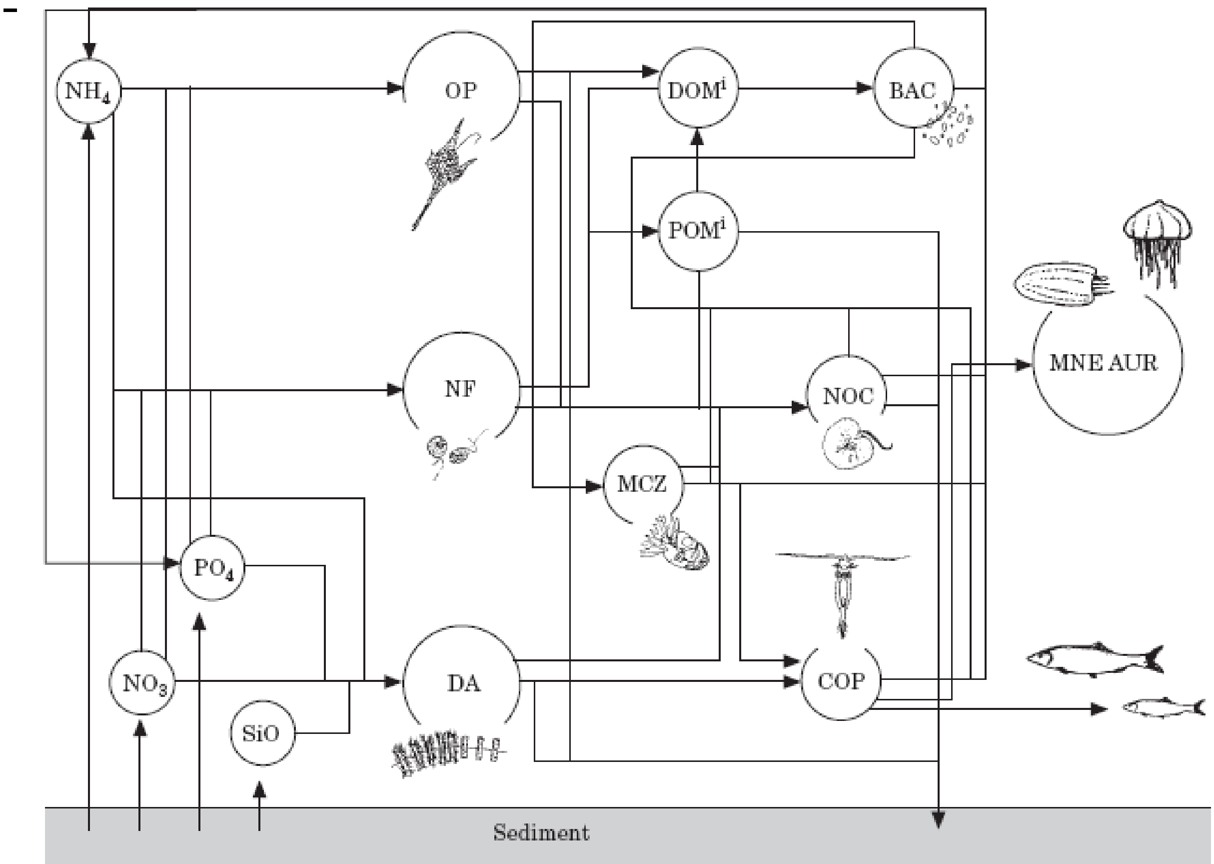

Fig. 1 Diagrammatic representation of the structure of the BIOGEN model.

3. Results

Figure 2 demonstrates the nutrient variability for several locations within the Varna Bay over the spring-summer seasons for the period from 2000 to 2013. Linear trends of observational data are plotted as well. It is clearly seen that for most of the nutrient there is a general decrease of the concentration during the last decade (except for the silicate concentration for Chanal area. The trend of decreasing of nutrient concentrations over Varna Bay coastal areas is even more pronounced for the summer season (Fig. 2). Phytoplankton during 2000-2013 (Fig. 3) was featured by an overall decrease of total biomass (and chlorophyll-a), lower frequency of phytoplankton blooms although still observed, on the expense of pronounced alterations of community structure (increased dominance of species from not habitual for the Black Sea classes) introducing shifts in the taxonomic ratios of the phytoplankton assemblages.

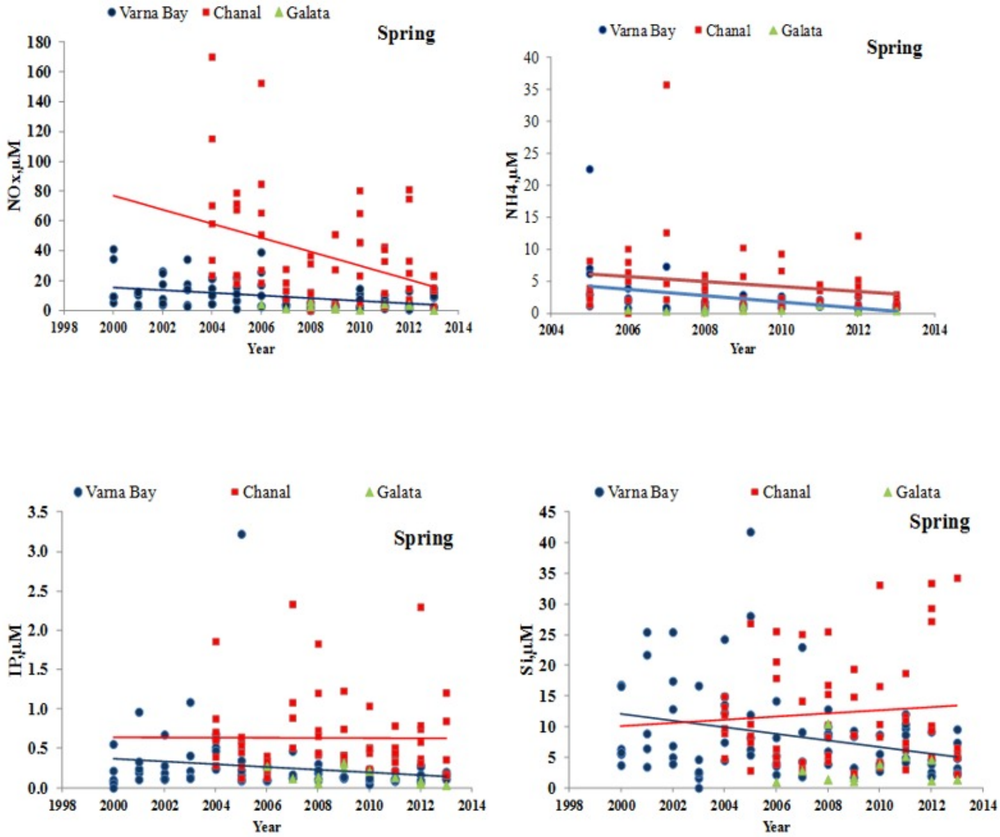

Fig. 2 *Times series of Nutrients averaged over spring for different Varna Bay location*

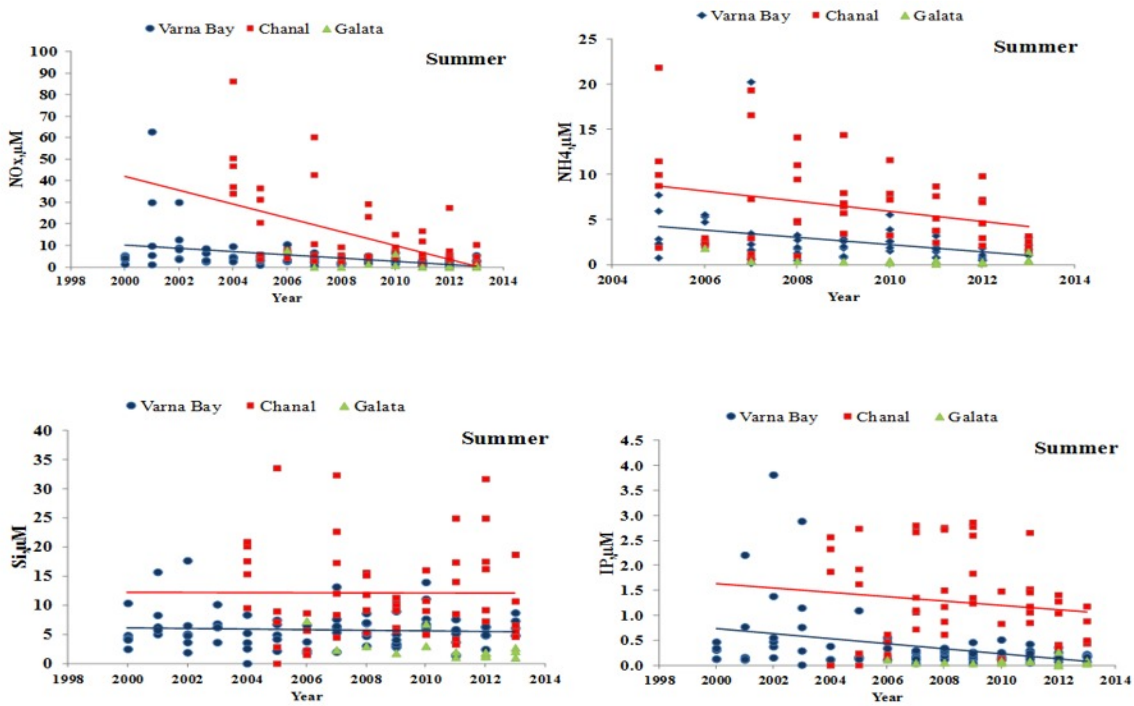

Fig. 3 *Times series of Nutrients averaged over summer for different Varna Bay location*

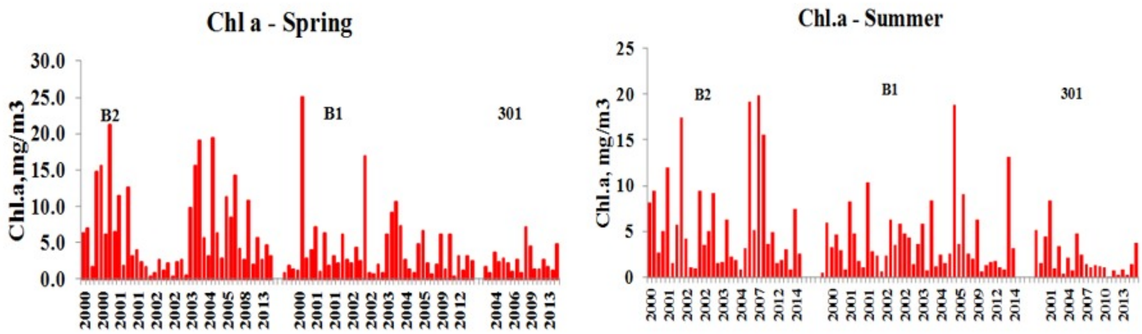

Fig. 4. *Long-term (2000-2014) variability of chl.a time series in spring (Left) and summer (right) (B2-Chanal, B1- Varna bay, 301- Galata stations in Varna area)*

The Phytoplankton concentration for spring season as an indicator for the Black Sea ecological state is demonstrated on Figure 5: The classification of the values for this indicator and five ecological states is presented in the table on the bottom-left site. Temporal variability of the phytoplankton concentration is analyzed from 2001 until 2014 taken from the observations (left) and model simulations (right). The shadings correspond to the ecological state as defined by Table1: bad (red), poor (orange), moderate (yellow), good (green) and high (blue) state of the sea. The data from the numerical simulations have been extracted for the same locations and time as the observational ones. It is clearly seen that there is a good agreement between model and observations giving the confidence that the model simulations could be used as a powerful tool for assessing the Black Sea ecosystem status. The interannual variability of the phytoplankton is relatively well reproduced by the model simulation compared with observations. Both patterns show a clear trend of improving the ecological status for the Varna Bay region from moderate to good during the last decade. Only for the period 2009-2010 the ecological status has been again shifted to moderate-poor due to the increase of the nutrients. Several scenario has been performed in order to study the response of the Varna Bay ecosystem to both climate change and nutrient variability and this will be discuss as well.

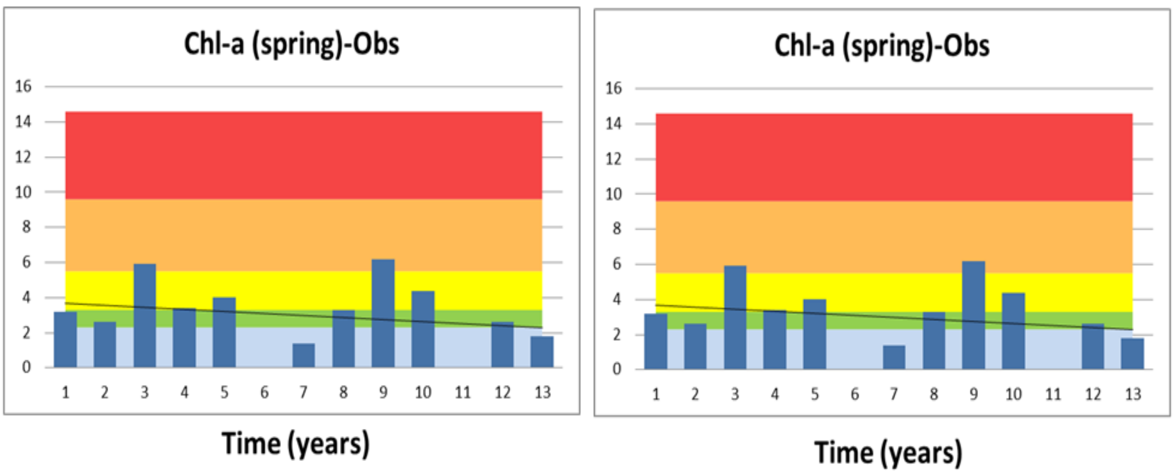

Fig. 5 *Chlorophyll concentration as an indicator for the Black Sea ecological state: Temporal variability of this indicator from 2001 until 2013 - from the observations (left) and model (right). The shadings correspond to the ecological state as defined by Table1: bad (red), poor (orange), moderate (yellow), good (green) and high (blue) state of the sea*

4. Conclusions/Discussion

4. Conclusions/Discussion

Among the main challenges in the implementation of WFD and MSFD is the growing demand for robust and reliable methodological approaches in selecting indicators for diagnose of the ecological state taking into account the complexity of multifactor drivers/pressures. The indicators computed based on both observational data and modelling results will be further used as a tool for socio-economic evaluation of the ecosystem status of the coastal waters. The aim of this study was to support for the policy advice to stakeholders/ governments on the need to invest in nutrient reduction projects. We aim to answer on which are the driving forces and responses of the marine systems to both anthropogenic and/or climate changes? Developing integrated tools for assessing marine ecosystem status is one the major outcomes of such a study.Text

5. Acknowledgements

The study was supported by PERSEUS Project funded by the EU under FP7 Theme "Oceans of Tomorrow" OCEAN.2011-3; Grant Agreement No. 287600

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Phytoplankton dynamics in the hydrologically complex NE Aegean frontal area (NE Mediterranean)

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Abstract

In order to further elucidate the role of modified Black Sea waters in triggering productivity in the NE Aegean Sea, within the framework of Perseus-IP and AegeanMarTech projects a study of hydrology and phytoplankton related biochemical variables was conducted along a N-S transect during October 2013. Visiting stations across this N-S transect, allowed water column sampling with surface BSW of variable residence times in the area, from older in the north, to newly advected BSW, in the south. The typical profiles of oligotrophic N. Aegean waters during the thermally stratified fall period along the largest part of the section and the pronounced maxima in all biochemical variables within the fresh surface BSW in the south revealed the explicit "fertilizing" effect of BSW for the N. Aegean area.

Keywords: primary production, Black Sea Water (BSW), NE Aegean Sea, Chlorophyll a, picoplankton

1. Introduction

The pelagic ecosystem in association with the dominant hydrological features of the dynamic frontal NE Aegean area have been studied in a series of research projects over the last 20 years. The less saline, nutrient enriched waters originating from the Black Sea (BSW) outflowing into the Aegean through the Dardanelles Straits are shown to drive ecosystem productivity and food web functioning (Siokou-Frangou et al., 2002). Phytoplankton biomass and activity are dominated by the smaller size classes of picoplankton (60-80%), often attaining higher productivity levels in the NE Aegean area (Ignatiades et al., 2002). In this work, we aim to further elucidate the variability of phytoplankton community structure and activity in response to the spreading and evolution of BSW within the frontal NE Aegean Area. Thus, a section encompassing different stages of modified surface BSW ("fresher" to "older") and Levantine waters (LW) is visited and sampled for most biochemical and phytoplankton related variables. This is directly related to Descriptor 5 - Eutrophication of the MSFD.

2. Materials and methods

The work presented here was conducted during the Perseus AEGEX cruise and the first AegeanMarTech (1AMT) cruise, performed back to back in October 2013 (5-9 and 10-12/10, respectively), on board the R/V Aegaeo in the NE Aegean Sea. A total of 15 stations were sampled for biochemical parameters, 8 in Perseus and 7 in AegeanMarTech. Here, a selection of 12 stations is presented, located along a north-south transect over the deep Skyros trough, in the north, and the shelf area at the vicinity of the Dardanelles Straits, in the south (Fig. 1). Seawater sampling was performed with a rosette sampler within the euphotic zone (0-100 m) at 6 or 7 standard depths according to the bathymetry of each station. Conductivity-temperature-depth (CTD) and oxygen profiles were collected at all stations and salinity was used as the basic descriptor for distinguishing the Black Sea (BSW) and the Levantine water (LW) masses. Nutrients were measured according to standard analytical procedures (Mullin & Riley, 1955, for silicate; Strickland & Parsons, 1977, for nitrate-nitrite-ammonium; Murphy and Riley, 1962 (Perseus) and Rimmelin and Moutin, 2005 (AegeanMarTech), for phosphate). Details for nutrient analyses can be found in Souvermezoglou et al. (2014). Chlorophyll *a* concentration was measured by size-fractions (pico-, nano-, total) according to the fluorometric method (Holm-Hansen et al., 1965) and primary production was performed according to 14C isotopic incorporation method (Steemann-Nielsen, 1952) in 5 selected stations. Details for both methods are presented in Lagaria et al. (2013). Phytoplankton taxonomic groups were identified by inverted microscopy and HPLC analysis.

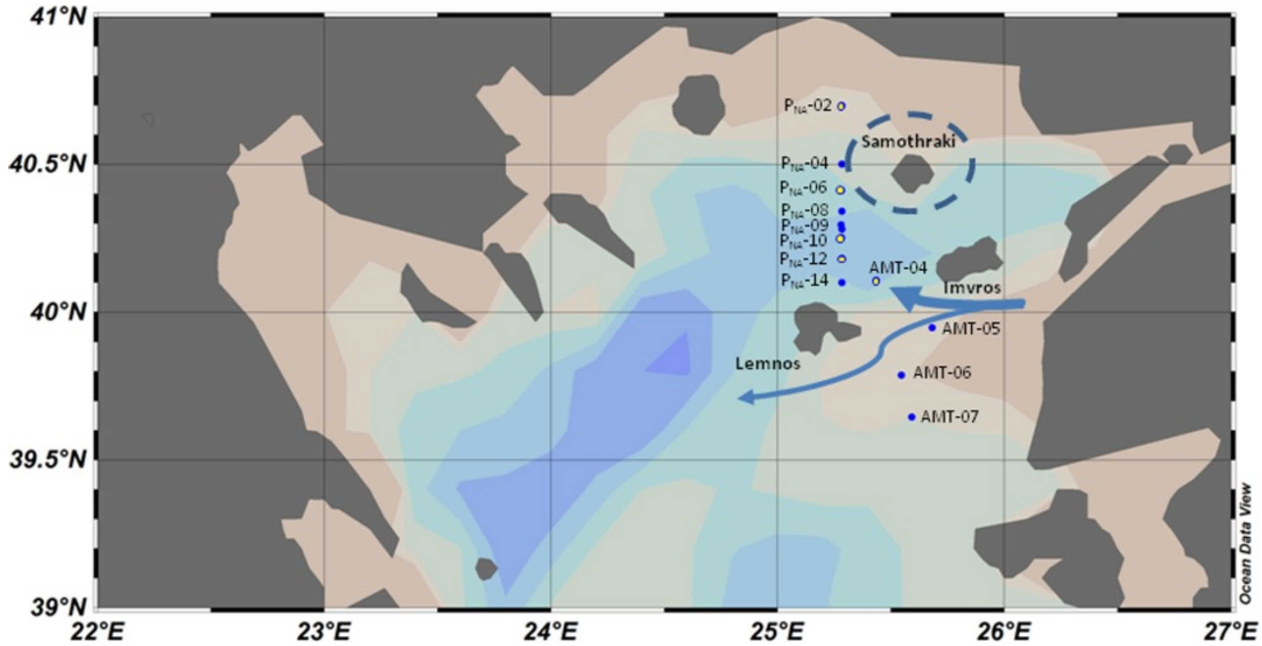

Fig. 1 *Study area and sampling stations location along the N-S transect in the NE Aegean Sea. Circulation patterns are also depicted (arrows indicate outflowing BSW course and dashed line the Samothraki anticyclone). Light circles: stations (5) where primary production experiments were conducted.*

3. Results

During October 2013, a strong thermocline was developed with temperatures > 20^{o}C in the upper 30 m, dropping to ~14 ^{o}C down to 100 m (Fig. 2a). The warm surface layer was occupied by "older" BSW (~ 35 psu) towards the north, entrapped in the area under the influence of Samothraki anticyclone (Fig. 1), and fairly "fresher" BSW (31-33 psu) towards the southeast (Stations 1AMT 4-6), over the shallow shelf area northeast of Limnos Isl. (Fig. 2b). Below 50 m the entire area is filled with waters of Levantine origin (LW).

The BSW surface layer was only interrupted in the middle of the transect north of Lemnos Isl. (St. pna-10 & 12), where LW over the deep trough almost reached the surface, denoting that the main spreading direction was from the Dardanelles towards the W-NW (Fig. 1). Nutrients (PO_4, NO_3+NO_2, SiO_4) were depleted in the surface 0-50 m layer, except from the core of BSW in the south where they peaked at surface and the bottom (Fig. 2c, d, and f). Oxygen concentrations were also lowest at surface and peaked in the subsurface layer of 50 m as well as in the core of BSW (Fig.2h). Chl-*a* concentrations presented typical deep maxima (DCM) at a layer around 50 m (< 0.3 μgL^{-1})

while they also showed elevated values within the BSW core, essentially attributed to larger cells (Fig. 2g, i, j).

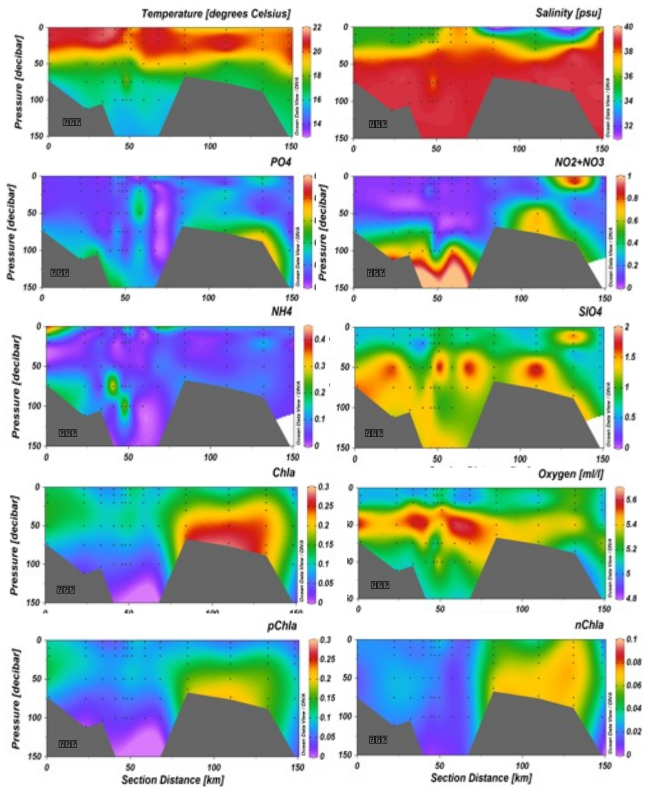

***Fig.2** Spatial distributions of temperature, salinity, oxygen, nutrients, and Chla by size fractions ('pChla' and 'nChla' for the pico- and nano-fractions, respectively) for the sampled north-south (left to right) cross section during October 2013. Dotted vertical lines represent the CTD casts at each sampled station.*

Primary production (PP) displayed typical vertical profiles with maxima (0.4-1.0 $mgCm^{-3}h^{-1}$) in the 0-20 m BSW layer, decreasing gradually down to 80 m (< 0.2 $mgCm^{-3}h^{-1}$). Interestingly, at the core of BSW (St. 1AMT-4) PP was twice as high as at the rest of stations down to 50 m (Fig. 3a). In the same time, mean integrated PP values in the water column were 3-fold higher in the BSW core than in the rest of stations, whereas at the northernmost coastal station (pna-02) it was 2-fold higher (Fig. 3b). Maximal PP values in the BSW core were associated with similar increases in both phytoplankton size classes (Fig. 3b), as also confirmed by HPLC and microscopic analysis, with maximal zeaxanthin (biomarker of picoplankton cyanobacteria) and diatom concentrations (data not shown) within the surface BSW "lens" (Fig. 2b).

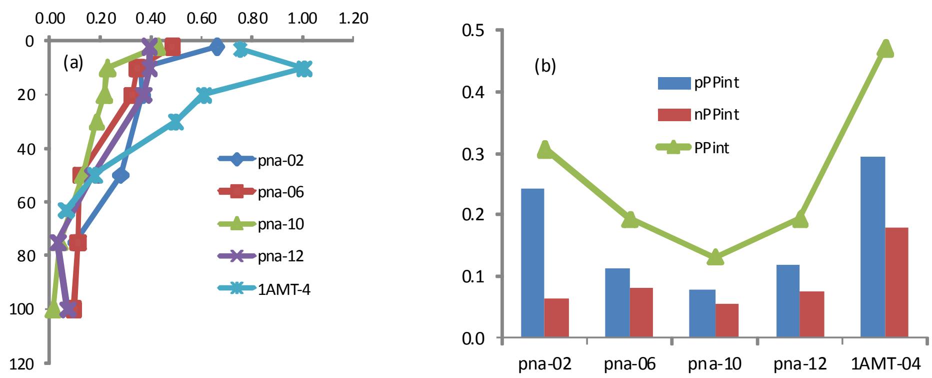

***Fig. 3.** Primary production ($mgCm^{-3}h^{-1}$) along the N-S transect: (a) Vertical profiles, (b) water column mean integrated values at the 5 stations.*

4. Discussion and conclusions

During mid fall 2013, analyses of hydrographic and phytoplankton related biochemical variables across a N-S cross section of stations revealed interesting patterns in both the vertical water column structure and the horizontal distributions of surface BSW masses. Based on the dominant circulation patterns in the area (Fig. 1), the N-S horizontal section incorporates in the same time the temporal evolution of the modified surface BSW masses, with "older" BSW partially mixed with LW constrained in the north from the previous winter (Zervakis & Georgopoulos, 2000) and freshly advected BSW "sliding" over the Levantine waters from the southeast towards a NW direction. The cross sections of the studied variables (Fig. 2) revealed typical vertical distributions during the thermally stratified fall period of the oligotrophic N. Aegean, as previously recorded in the area (Ignatiades et al., 2002; Lagaria et al., 2013) with warm surface modified BSW masses depleted from nutrients, in one hand, and Chl*a* and oxygen concentrations presenting maxima in the Levantine layers below surface, in the other. The deep Chl*a* maxima are associated with the nutriclines at the same depths and may represent physiological adaptations to reduced light (increased Chl*a*/cell production) and not necessarily increased autotrophic biomass (in terms of carbon). As shown previously, primary production was highest within the surface BSW layer in all stations. On a horizontal scale, pronounced maxima recorded by all variables within a lens of freshly advected BSW in the south, revealed the "fertilizing" effect of BSW for the entire NE Aegean area. Large cell organisms, and in particular diatoms, were closely associated with the surface BSW masses outflowing from the Straits. Diatoms transferred by surface BSW could account for significant export in the NE Aegean and support grazing processes which fuel autotrophic production through remineralization of nutrients (Lagaria et al., submitted).

5. Acknowledgements

This research has been supported by the projects: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP) and "Technological and oceanographic cooperation Network for the Study of mechanisms fertilizing the North-East Aegean Sea" (AegeanMarTech, co-financed by the EU (ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" (NSRF) - Program: THALES).

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The eutrophication status of the Western Black Sea – a step towards GES assessment

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Abstract

The aim of this paper is to assess the eutrophication status of the Western Black Sea covering two EU Member States (Bulgaria and Romania) and one candidate country (Turkey), taking into account MSFD requirements of Descriptor 5 criteria. Data for nutrients, chlorophyll a, dissolved oxygen and transparency from seven summer cruises during 2012-2013, were analysed. Based on the BEAST output, the eutrophication status of the Western Black Sea in summer 2012-2013 covered all quality classes from “High” to “Bad”. Failure to achieve GES was found in all habitats (coastal, shelf and open waters) from Bulgarian and Romanian transects.

Keywords: nutrients, chlorophyll a, BEAST

1. Introduction

Among the set of problems in the implementation of the MSFD, the approaches to the overall assessment of Good Environmental Status (GES) and more specifically the principles of aggregation (including spatial integration) of indicators among and within Descriptors are a matter of continuous debate (Borja *et al*., 2014). Even if Descriptor 5 (Eutrophication) is assessed in the GAP Analysis elaborated under the FP7 PERSEUS Project, as relatively less problematic, in terms of level of understanding and data availability, the uncertainties associated with the definition of thresholds between GES/nonGES represent still a big challenge. Further difficulties stem from the uncertainties in the resolution of human versus climatic impacts, currently eutrophication seen as a complexity of processes conditioned by multiple physical / biological natural attributes that are modulated by various human impacts and climatic disturbances (Greene and Pershing, 2007). The aim of this paper is to assess the eutrophication status of the Western Black Seas covering two EU Member States (Bulgaria and Romania) and one candidate country (Turkey), taking into account MSFD requirements of Descriptor 5 criteria (Eutrophication) and based on an integrated approach.

2. Materials and methods

Data from water column samples (0-200m, N=223) were obtained during six (late) summer cruises (July-October) within 2012-2013 from 3 transects from Bulgaria, Romania and Turkey. One cruise, (July 2013,) was common for all 3 countries and conducted under the MISIS project and the others – under the National monitoring programs and PERSEUS project (Table 1).

Table 1: *Description of the network stations and BEAST qualitative results of eutrophication – Western Black Sea, 2012-2013*

No.	Station	Cruises (no)	Transect	Country	Pelagic Habitat	Bottom depth [m]	BEAST					
							July 2012	August 2012	September 2012	October 2012	MISIS July 2013	August 2013
1	301	4	Galata	Bulgaria	Coastal	23.0	H*	G		H	G	
2	302	3			Coastal	24.0	H	H		H		
3	303	4			Shelf	41.0	H	P		H	B	
4	MO10	1			Shelf	76.1					B	
5	305	4			Shelf	93.0	H	G		H	G	
6	MO8	1			Shelf	1167.0					H	
7	308	3			Open	1535.0	H	H		H		
8	309	3			Open	1475.0	M	M			G	
9	EC 1	2	East Constanta	Romania	Coastal	14.0				M		G
10	EC 2	4			Coastal	28.0			H	H	P	H
11	EC 3	4			Coastal	36.0			H	H	M	H
12	EC 4	2			Coastal	47.0			M			G
13	EC 5	3			Shelf	54.0			H		M	H
14	MO4	1			Shelf	65.0					P	
15	MO5	1			Shelf	100.0					H	
16	MO6	1			Shelf	500.0					G	
17	MO7	1			Shelf	1000.0					H	
18	MO18	1	Igneada	Turkey	Coastal	27.2					H	
19	MO17	1			Shelf	53.3					H	
20	MO16	1			Shelf	75.6					G	
21	MO15	1			Shelf	101.0					H	
22	MO14	1			Open	1118.0					G	

*H-High; G-Good; M-Moderate; P-Poor; B-Bad

Nutrients (phosphate, silicate, inorganic nitrogen species – nitrite, nitrate and ammonium), dissolved oxygen and saturation (OS%), chlorophyll *a* in the water column 0-200m were analysed and transparency (Secchi disc depth, SDD) was measured in-situ (Fig.1). Temperature and salinity were measured as support parameters. Based on the satisfactory results of the intercalibration exercise performed in July 2013, the datasets are comparable and valid to be used in a common assessment (Report on the MISIS cruise Intercalibration Exercise: Chemistry, 2014). BEAST (Black Sea Eutrophication ASsessment Tool) is a similar tool with HEAT (Helcom Eutrophication Assessment Tool) developed and used by HELCOM (HELCOM, 2014) built on the “One Out, All Out” principle. BEAST was proposed to the riparian countries by the Black Sea Commission through the Baltic2Black project [1].

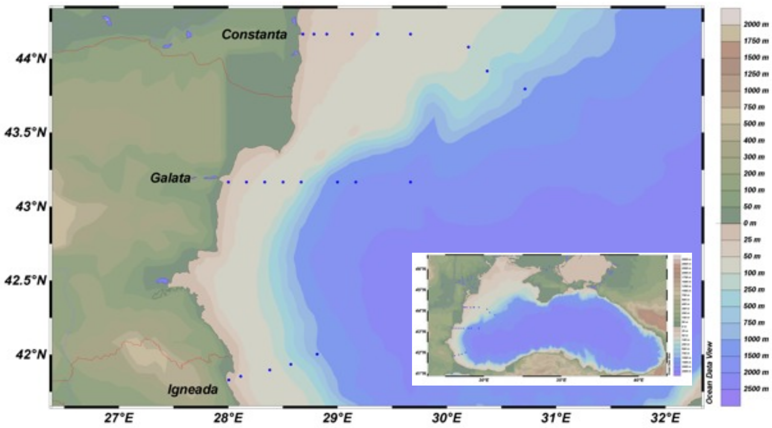

Fig.1 *Map of the transects - Western Black Sea, 2012-2013*

3. Results

BEAST is an integrative tool running under Microsoft Excel, flexible, allowing the expert to choose the parameters involved in the assessment. Thus, based on their availability and existing reference values for all three countries a core set of indicators was chosen in respect with Descriptor 5 criteria (MSFD) (Table 2). Parameters were grouped as follows: causes of eutrophication – nutrients levels (surface concentrations of phosphate and nitrogen oxidized forms); direct effects of eutrophication – surface chlorophyll a concentration as a proxy for biomass and indirect effects of eutrophication – bottom OS% (down to 50m bottom/water column depth due to the Black Sea’s hypoxia natural features) and transparency (SDD). The tool was applied for each station to surface data (N=47).

Table 2: *Reference values for the indicators used for the eutrophication assessment according to BEAST*

<table>
<tr><th rowspan="2">Habitat</th><th colspan="3">PO4, µM</th><th colspan="3">TNOx, µM</th><th colspan="3">Chl a, µg/L</th><th colspan="3">SDD, m</th><th colspan="3">Bottom DO, %</th></tr>
<tr><th>BG</th><th>RO</th><th>TR</th><th>BG</th><th>RO</th><th>TR</th><th>BG</th><th>RO</th><th>TR</th><th>BG</th><th>RO</th><th>TR</th><th>BG</th><th>RO</th><th>TR</th></tr>
<tr><td>Coastal (>30m*)</td><td>0.25</td><td>0.15</td><td rowspan="3">0.15</td><td>1.5</td><td>4.0</td><td rowspan="3">0.5</td><td>0.8</td><td>3.90</td><td rowspan="3">1.00</td><td>7.0</td><td>7.5</td><td rowspan="3">5.0</td><td colspan="3" rowspan="3">80</td></tr>
<tr><td>Shelf (31-200m)</td><td>0.20</td><td>0.20</td><td>1.0</td><td rowspan="2">2.0</td><td>0.6</td><td rowspan="2">2.05</td><td>10.0</td><td>9.0</td></tr>
<tr><td>Open (>200m)</td><td>0.10</td><td>0.20</td><td>0.8</td><td>0.2</td><td>18.0</td><td>9.0</td></tr>
</table>

***Station bottom depth**

The eutrophication status scores separated in GES and non-GES categories by the Good-Moderate threshold, revealed that 76% (N=36) values corresponded to GES, while 24% (N=11) not (Fig.2L). Failure to achieve GES was found in all habitat types: coastal/shelf (RO) and shelf-open sea (BG) (Fig.2R). In the absence of main land-based sources (including rivers) on the Turkish transect it is to note that the result could still be influenced, by a smaller amount of data from a single cruise only.

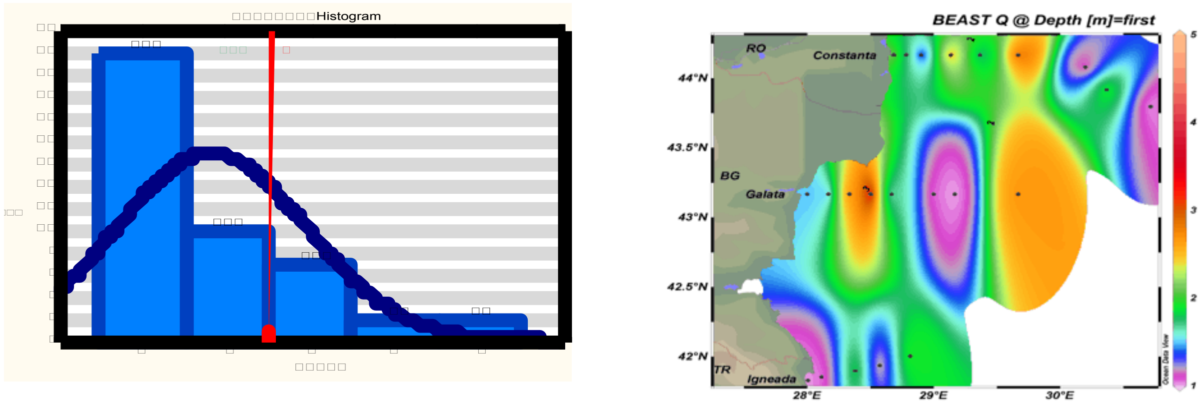

Fig.2 *Histogram (L) and surface horizontal distribution (R) of BEAST scores in the Western Black Sea, 2012-2013*

Due to the land-based sources, "Hot Spots" on the Romanian littoral – Danube, municipal and industrial sources, coastal waters are usually affected by eutrophication particularly in the warm season when water stratification is predominating. Thus, the reasons GES was not achieved were combined causes (phosphate concentration) and indirect effects (bottom oxygen deficiency and transparency). For the Bulgarian shelf waters, albeit the equally weighting of indirect effects criteria - dissolved oxygen and transparency - led to a "moderate" status, due to the OOAO principle, it was chlorophyll a to decide the "Bad" status (the differences in the thresholds should also be noted). Nevertheless, in this case, both direct and indirect effects of eutrophication failed to reach GES in the area. BEAST scores spatial distribution was similar to both phosphate and silicate patterns even if the latter was not directly included in the evaluation (Fig.3)

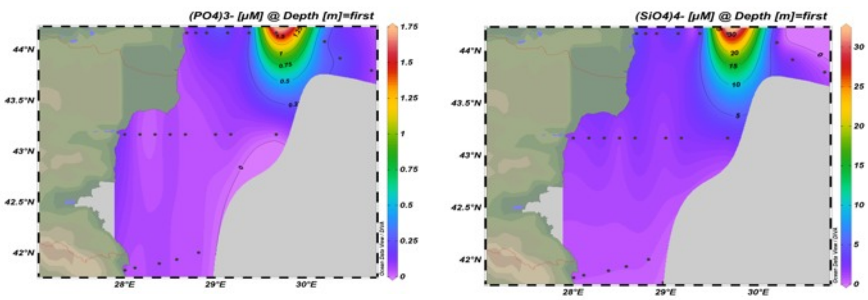

Fig.3 *Phosphate (L) and silicate (R) surface distributions in the Western Black Sea (2012-2013)*

Analysing the vertical phosphate distribution along the Romanian transect, it was found the maximum value on the edge of the inner shelf at the water-sediment interface (station MO5) in July 2013 (Fig.4). At the same location were identified small manganese nodules enriched with excessive Ni and Cu (MISIS, 2014) which formation promotes also the precipitation of phosphorus and many other elements (Baturin et al., 2002). Meanwhile, the local hydrographic conditions defined by the position of thermocline, the prevailing winds of NW and W directions as the most important factors that determined the structure and intensity of the horizontal water circulation (MISIS, 2014) suggest that the "Poor" status was observed in a dynamic biogeochemical area and was not particularly linked to local land-based sources. On the other hand, PO_4 concentrations in sea water depend on a complexity of processes and the balance between rivers loads, uptake and burial in the sediment

(Dijkstra et al., 2014). As recent inventories showed that Danube's PO_4 input decreased in the last years (ICPDR, 2012), most likely the contribution of other rivers in the area (Dnieper, Dnister, Bug) should not be neglected, underlying the transboundary nature of eutrophication phenomenon.

4. Conclusions/Discussion

Eutrophication status of the Western Black Sea showed high variability in (late) summer 2012-2013 covering all ecological status, from "High" to "Bad". Failure to achieve GES was identified in coastal and shelf waters (RO) and shelf and open waters (BG) driven by different factors. Thus, in the coastal area, through the moderate phosphate concentration it is emphasized the land-based sources (including rivers) influence. On the Romanian shelf, phosphate and silicate concentrations were highest both at the surface and water-sediment interface. Meanwhile, the bottom oxygen deficiency/hypoxic conditions in the area, could lead to phosphorus recycling from sediments and fuel a secondary enrichment of the water column.

The results revealed that the non-GES ecological status was also highly influenced by the currents and winds regime and associated water circulation in the surface layer in the shelf and open waters. Whilst it is underlined the transboundary character of the eutrophication phenomenon which might have drivers distant to its effects suggesting the strong need of a regional approach of assessment of drivers/pressures/impacts interplay on eutrophication.

The results highlight the need to better understand/define the threshold between natural variability (including climate change) and anthropogenic impact in order to correctly evaluate the Good Ecological Status according to descriptor 5 which particularly imply "human induced eutrophication", associated mostly with coastal areas.

5. Acknowledgements

Data from July 2013 were collected under DG ENV MISIS Project "MSFD Guiding Improvements in the Black Sea" GA No. 07.020400/2012/616044/SUB/D2MISIS and BEAST tool was developed under Baltic2Black Project "Environmental Monitoring of the Black Sea with focus on nutrient pollution". The work was performed under PERSEUS Project WP1 and WP2.

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Session 2

The force of the Atlantic on the Mediterranean, not always a positive influence: an inter-annual analysis on fish and jellyfish.

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Abstract

The Strait of Gibraltar, an unique hydrological framework, replenishes the Mediterranean with Atlantic waters through an intense eastward current known as the Atlantic Jet (AJ). In this work, the effect of the AJ and its influence of circulation patterns in the Alboran Sea over the fish (anchovy) life cycle and jellyfish sightings (Rhizostoma luteum and Physalia physalis) has been analyzed. We performed a comprehensive analysis of the environmental conditions (biotic and abiotic) associated with the P. Physalis swarm events in 2010, landings of anchovy and appearance of R. luteum (a rare giant jellyfish not reported since 1959).

Keywords: Strait of Gibraltar, Alboran Sea, anchovy, Rhizostoma luteum, Physalia physalis

1. Introduction

The Alboran Sea and the Strait of Gibraltar play a crucial role in the overall Mediterranean dynamics, acting as its interface with the Atlantic Ocean. Exchange through the Strait of Gibraltar is carried out in a typically anti-estuarine circulation, with surface Atlantic waters (the Atlantic Jet, AJ) flowing into the Alboran Sea and an outflow of Mediterranean waters in the layer below (e.g., Armi & Farmer, 1985). In the Alboran Sea there are no important river discharges, the tidal influence is low, the continental shelf is narrow and one of the main drivers of primary productivity in the region is the inflow of Atlantic waters through the Strait of Gibraltar (Macias et al., 2007b). The biogeochemical composition of the AJ is dependent on several aspects like the original characteristics at the Gulf of Cadiz (Navarro et al., 2006), the coastal-channel interactions (lateral cross-shelf mixing) driven by tidal motion within the Strait (e.g., Vazquez et al., 2009; Navarro et al., 2011) and the interfacial mixing along the channel of the Strait (e.g., Macias et al., 2006; 2007a). Any changes in the AJ characteristics have a large influence on the dynamics and productivity of the pelagic ecosystem of the Alboran Sea (e.g., Ruiz et al., 2001; Macias et al., 2009; Oguz et al., 2013). In one hand, the AJ fertilizes the southwestern Mediterranean and is considered to be the ultimate factor responsible for the comparatively high fish production of this region. At the other hand, the jellyfish is an excellent target to study the inter-basin exchanges variability through the Strait of Gibraltar. Some of the species are originally from open Atlantic Ocean (as the Portuguese Man-of-War), or they are rarely observed in the NE Atlantic (as the *Rhizostoma luteum*). In this work, will be analyzed the meteorological and oceanographic conditions in 2010 of the North-East Atlantic Ocean during the months previous to the appearance of Portuguese Man-of-War (*Physalia physalis*) in the Mediterranean Sea, which cause the region's first recorded human fatality attributed to a jellyfish sting (in Sardinia, Italy) (Haywood, 2010). *Physalia physalis* is a pleustonic colony of polypoid and medusoid organisms, and it is equipped with a particularly potent toxin that is potentially deadly to humans.

2. Materials and methods

Fisheries data; Several data sources have been used to compile the time series of anchovy landings and CPUE in the Alboran Sea. In addition, a precise analysis of the historical information for the small pelagic fishery in the basin is also available. The yearly catches analyzed here include data after 1986, when this fleet only landed catches from fishing grounds north of 36◦N. The Port of Malaga registers almost 85% of all of the anchovy landings of the northern Alboran Sea, and after several corrections for anchovy fished elsewhere but disembarked at Malaga port, the data of anchovy landed in the Port of Malaga are routinely used to assess landings in the N. Alboran Sea. The CPUE data from the General Fisheries Commission for the Mediterranean (GFCM) and other reports exactly coincide at the years of overlapping (1990 to 1995), indicating that both are the same series of data. Since the late 1990s, the fishery has been closed between March and April, and the seasonal analyses presented in this paper exclude these years. All of the available assessments of this fishery indicate that recruits (age 0) support the bulk of the fishery, and therefore, that the peak of catches in Autumn/Winter are the result of spawning in the preceding Spring/Summer. In addition, these assessments also indicate that CPUE is a good index for the relative abundance of spawners in the area, what is also evident in the averages of both age in catches (0.63±0.23SD) and the percentage of mature individuals at age 0 and 1 (60.7±18.8SD and 95.8±6.6SD respectively).

Altimetry data; The absolute dynamic topography (ADT) data are delayed-time (dt) gridded and merged products with a spatial resolution of 1/8º and weekly temporal resolution. These data were provided by AVISO (http://www.aviso.oceanobs.com), covering the entire Mediterranean Sea and combining information from different missions, significantly improving the estimation of mesoscale signals. The KE is calculated as: $KE = (u^2 + v^2) / 2$, where the velocity components, u and v; were derived from the geostrophic approximation:

$u = - (g/f) (\partial h/\partial y)$, and $v = - (g/f) (\partial h/\partial x)$, where h is the ADT, g is the gravitational acceleration, and f is the Coriolis parameter.

To investigate the combined spatial and temporal covariability between ADT data and CHL, a singular value decomposition (SVD) technique was employed. The SVD was performed on the cross-covariance matrix between the non-normalized values of each field (CHL anomalies and ADT anomalies) to identify pairs of coupled spatial patterns and their temporal variation. The first SVD mode is associated to changes in the sea level of the whole basin in response to variations of atmospheric pressure, whereas the second mode synthesizes the dynamics of circulation structures that are able to control anchovy recruitment in the Alboran Sea.

Sea surface temperature data; The SST data used in this study correspond to AVHRR Ocean Pathfinder SST and MODIS L3 SST 4. The AVHRR Ocean Pathfinder SST data were obtained from the Physical Oceanography Distributed Active Archive Center at the NASA Jet Propulsion Laboratory, (http://podaac.jpl.nasa.gov/). We used the 4 km Pathfinder version 5 SST Project, which is a new reanalysis of the earlier AVHRR version of the Pathfinder data set that has been distributed since the early 1990s. We used the monthly nighttime data and the period was comprised between 1998 and 2009. The MODIS L3 SST 4 were obtained from the Oceancolor website (http://oceancolor.gsfc.nasa.gov). We used the monthly nighttime data with 4 km of spatial resolution for years comprised between 2010 and 2011.

Sea surface color data; Sea surface chlorophyll a data were downloaded from the GlobColour Project (http://www.globcolour.info/). This source produces global ocean color maps (Level-3) by merging data since 1998 from the three sensors SeaWiFS, MODIS and MERIS. Surface CHL data correspond to a product of CHL case I water based on the GSM merging method. This method provides the best fit to *in situ* CHL concentration and has the added advantages of providing other products and allowing researchers to calculate pixel-by-pixel error bars. With these data sets, the cloud cover is reduced, and therefore, more useful images become available. The spatial and temporal resolutions of these composite images were 4.6 km and monthly, respectively.

North Atlantic Oscillation index; The Winter (December through March) index of the NAO were provided by the Climate Analysis Section (NCAR) (Boulder, USA).

Jellyfish data; Sightings of living and stranded specimens of *Rhizostoma luteum* on the Atlantic coast of Morocco and along the south shore of the Iberian Peninsula in June-July 2012 and in January-February 2013 had been compiled and reported. Of this rare giant jellyfish (it was last scientifically reported in 1959), we performed for the first time the analysis of mithocondrial cytocrome *c* oxidase I (mtCOI). We compiled all of the available information regarding *P. Physalis* arrivals along the coast over several years.

Model; We performed a model simulation of the drifting of individual siphonophores coupling a hydrodynamic model to an individual based model (close linked to WP4 work). This consisting of a ROMS based numerical simulation forced with realistic winds (ASCAT) and heat fluxes from

ERA-Iterim, together with an Individual Based Model (IBM) simulations. The hydrodynamic model simulates water movement and physical oceanic conditions of the Gulf of Cadiz and Alboran Sea regions while the individual based model track the drifting path of each individual colony under the combined action of currents and wind drift. Model estimated beaching patterns of *P. Physalis* were compared with available observations at both sides of the Strait of Gibraltar for Winter/Spring of year 2010.

3. Results

There is no evident connection between proxies for abundance (CPUE) and chlorophyll at the time of spawning (Fig.1.c; $r = -0.403$; $p > 0.15$), when early stages demand high food concentrations.

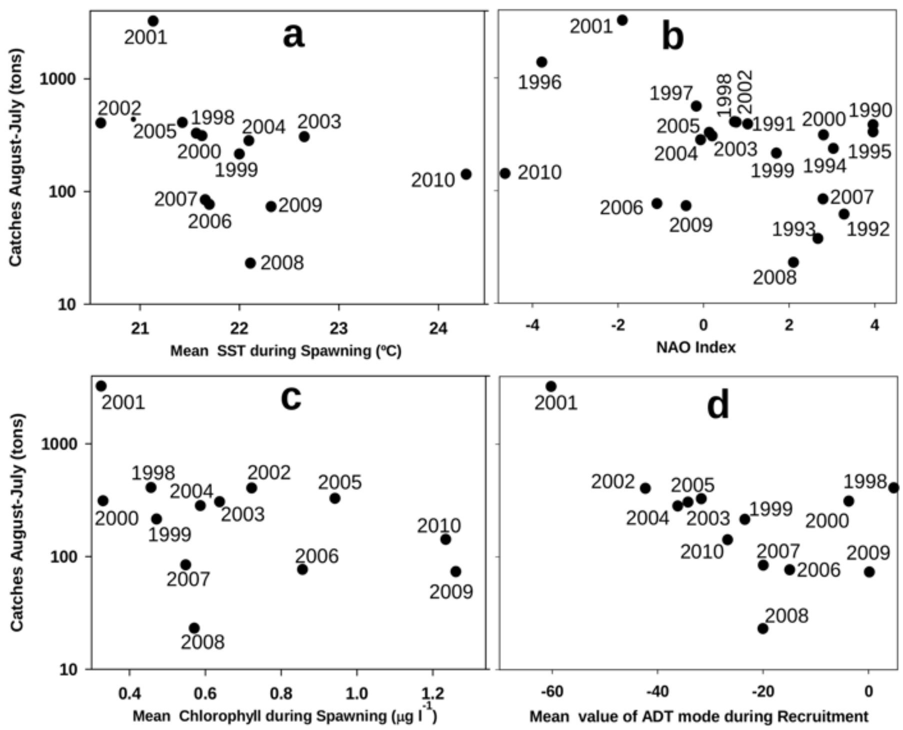

Fig. 1 *Recruitment versus SST, NAO, chlorophyll concentration and ADT mode. The figure shows the landing of Fig. 1.b versus the mean of (a) SST and (c) chlorophyll concentration at the shelf during spawning period (June to September) as well as (b) the NAO index and (d) the expansion coe�cient of the ADT second mode during recruitment (October to December).*

Despite the control that temperature may exert on the survival of fish larvae (Pepin, 1991), the correlation between SST during the spawning season and subsequent catches is also low (Fig.1.a; $r = -0.332$; $p > 0.20$). Large-scale environmental indexes, such as NAO, also exhibit poor explanatory power (Fig.1.b; $r = -0.295$; $p > 0.30$), and only ADT at the time of recruitment seems to be connected with catches (Fig.1.d; $r = -0.625$; $p < 0.05$). Moreover, a time-lag analysis of recruitment shows that this (0-lag) correlation between ADT and recruitment is the only significant correlation in the series (Ruiz et al., 2013).

In the case of the jellyfish *Rhizostoma luteum*, during summer 2012 and following the dominant currents, the jellyfish first appeared in the Gulf of Cadiz west of the Strait of Gibraltar. Subsequently, seven additional sightings were reported east of the Strait, in the Alboran Sea. In winter 2013, another event of stranded individuals of this species occurred in the Gulf of Cadiz (Prieto et al., 2013).

The year 2010 registered an unusual record of *Physalia* sightings along the Mediterranean Sea (at Atlantic and Mediterranean coastlines) and Canary Islands (North East Atlantic). This was an outstanding year in the frequency of occurrences, but also in the total number of colonies arrived (more than 100,000 colonies), compared to 2009 and 2011 that they were less than 60 colonies. The oceanic population of *Physalia physalis* started to appear stranded on the beach on February 22nd 2010. Then the observations on the coast occurred from West to East advancing towards the Mediterranean, passing the Strait of Gibraltar and to the far East of the Alboran Sea. The 2009–2010 winter had one of the most negative NAO indices (−4.64) measured during the nearly 150-year record. This climatic condition favoured a stormy mid-latitude Atlantic, with increased storm activity and rainfall in southern Europe, the western Mediterranean and North Africa. Therefore, the climatic/oceanographic conditions have been analyzed of that particularly year, which pointed out to be one year of stronger westerlies winds in the NE Atlantic basin compared to the time series from 1979. The beaching timing observed is highly correlated to the simulated ($r=0.81$, $p<0.001$, $n= 18$). In summary, the results showed small differences in the overall estimated arrival of *Physalia* between the model experiment and the real observations (Prieto et al., 2015).

4. Conclusions/Discussion

The high kinetic energy of the Atlantic jet increases primary production but also negatively impacts the recruitment of anchovy. When the circulatory system collapses, it's possible to have an exceptional anchovy recruitment. Regarding jellyfish, this circulatory system allows entering in the Mediterranean Sea Atlantic species, with the consequent impact a different levels. The molecular phylogenetic analysis performed on the mtCOI gene sequence in specimens of *Rhizostoma luteum* confirmed the morphological classification, ratifying the *R. luteum* differs from *Rhizostoma octopus* and *Rhizostoma pulmo*. This study records the presence of this species for the first time in 60 years. At the other hand, the possibility that the particular/unique conditions that occurred during 2010 (and permitted the intrusion of *P. physalis*) will become more frequent greatly depends on the projected NAO patterns in future climate scenarios. In this sense, NAO projections remain one of the key uncertainties in future climate projections. Therefore, unless the NAO drifts toward more negative values under the influence of climate change recreating these so far unique meteorological conditions increasingly frequently, the 2010 *P. physalis* swarm event is unlikely to re-occur on a regular basis.

5. Acknowledgements

We thank PERSEUS (FP7-287600).

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Contrasting marine food web structures and time trends across the Mediterranean

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Abstract

We measured morphological traits and carried out multivariate analyses to ascribe 75 species to 10 functional groups (FG). Using bottom trawl survey data we calculated the relative changes in FG biomasses in 12 Mediterranean areas over the last two decades. Results identified four regions consisting of the South Adriatic and Ionian Seas, the Tyrrhenian Sea and around Sicily, around the Balearic islands and enclosed bays, and the North Adriatic and around Corsica. The biomass of all FG increased or remained stable in the first two regions while around half the FG decreased in the other two regions. Geographical patterns were explained by near bottom nitrate, temperature and mean catches.

Keywords: morphological traits, community models, food web structure, functional groups, temporal trends.

1. Introduction

With the development of the ecosystem approach to fisheries there is an increasing interest in analysing fish communities as sets of functional groups (FG). In fish ecology, classifying species in FG have been proved useful in investigating the influence of fishing pressure (Rochet et al. 2013), climate change (Travers-Trolet et al. 2014), and other environmental perturbations. Since nearly a decade, there has been a revive interest in developing a posteriori groups of species, with locally and species-specific morphological measurements. This interest takes up again ecomorphological approach that has evidenced a number of relationships between the morphology and function of species (Gatz 1979).

Grouping species according to traits is a way to simplify species-rich communities and increase the transferability of community models and/or allow the comparison of such models among ecosystems or geographic areas. Recent studies identifying and mapping different components of diversity and anthropogenic pressures in the Mediterranean Sea, have underlined significant geographical patterns (Mouillot et al. 2011). Concurrently, species composition of the Mediterranean marine communities also vary among geographic areas, so the functional approach seems very well suited to analyse Mediterranean communities. The main objective of this study is to describe community structures across the northern shores of the Mediterranean Sea using the morphological trait-based approach and to explain spatial and temporal patterns over the last two decades by environmental characteristics.

2. Materials and methods

This work is based on biological data (i.e. fish and invertebrate biomass) that were collected during annual bottom trawl surveys conducted in May-July from 1994 to 2012 in 12 so called GSAs (general statistical areas) in the northern part of the Mediterranean Sea (Fig. 1). Hauls were performed over the continental shelf (10 m to 200 m depth) and the continental slope (200 m to 800 m) within the framework of the MEDITS scientific project (Bertrand et al. 2002). All the fish and invertebrate species were weighted and counted. For the purpose of this study only biomass data are used. Concurrently to biomass data, 10 morphological traits (8 continuous and 2 categorical) were measured in the field and on pictures, by mean of the ImageJ software (version 1.47, http://imagej.nih.gov/ij/), taken between 2011 and 2013 MEDITS surveys (Brind'Amour et al. submitted). Among the chosen traits, eight of them were already proved useful in determining functional groups of species (Albouy et al. 2011). A total of 1523 individuals from 75 fish species were collected. For each species, continuous traits were computed as the mean values of up to ten sexually mature individuals after standardising them by body length.

Functional groups of species were defined such that only species displaying functional similarity (i.e. traits similarity) were grouped together. We conducted a hierarchical cluster analysis using Ward’s agglomeration method (Ward 1963) on the Gower’s distance of the species morphological traits matrix. The number of groups was statistically determined using the Silhouette criteria and also visually confirmed.

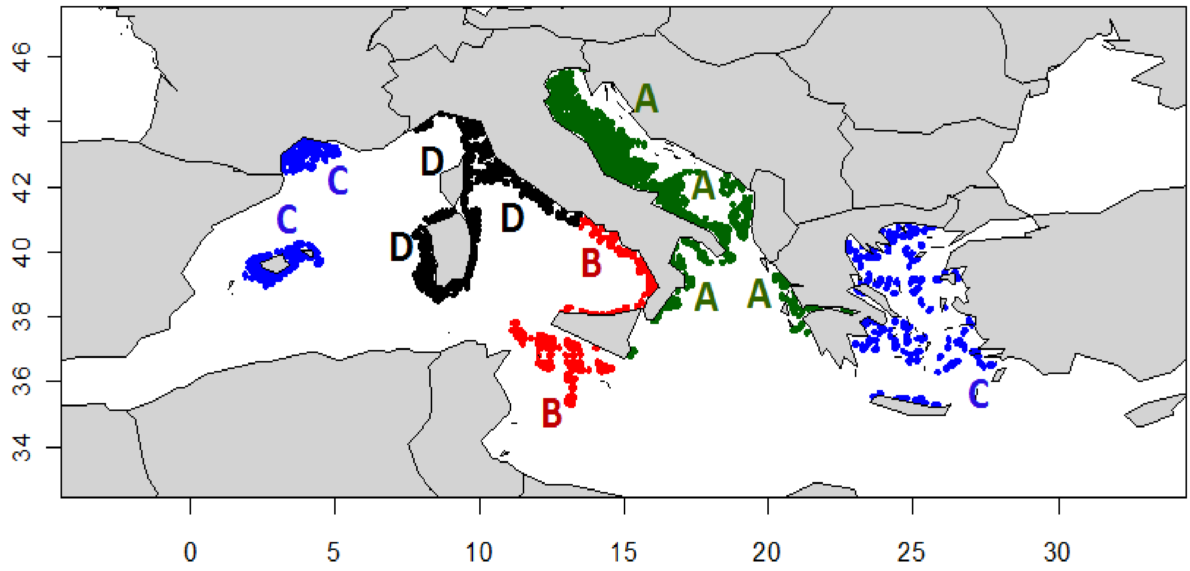

Fig. 1 *Sampling locations in the 12 GSAs included in this study. The colored letters correspond to the four geographical divisions of the GSAs according to the results of the Multiple Regression Tree.*

Temporal trends in functional group biomasses were summarized by computing the relative percentage difference in biomass between the mean biomass of the first three years (Bfirst) and the mean for the last three years (Blast) for each functional group ΔBFG=100 (BFG,last – BFG,first)/BFG,first.
A subset of My Ocean products (MyOcean 2014) was processed comprising monthly means for each of the six following variables: temperature (°C), salinity (psu), nitrate (mmol.m-3), chlorophyll (mg.m-3), primary production (mol.m-3.s-1), and dissolved oxygen (mmol.m-3). Concurrently to the environmental data we also extracted landings from the FAO database (FAO 2015). FAO data were filtered by selecting only the species composing the FGs. They were then aggregated by FAO division and divided by the surface areas given in Caddy et al. (1995). Interannual mean and standard deviation as well as the linear slope of the times series for all the environmental and landings data were used as explanatory variables. Relationships between relative FG biomass changes ΔBFG (response variable) and environmental drivers as well as landings (explanatory variables) were tested using multivariate regression trees (MRT; De'Ath 2002). All statistical analyses were conducted using R software (R Development Core Team 2010).

3. Results

The 75 species displayed a wide range of lengths ranging between 4 cm (Capros aper) to 122 cm (Lepidopus caudatus). They were assigned to ten functional groups according to their morphological similarity. Analysis of the morphological traits separated the species into two major clusters associated with their position in the water column (pelagic and bentho-demersal species). A gradient of species diets varying from invertebrate to fish feeders and habitat (vertical position in water column) was also identified within each major clusters.
Results from the MRT underlined the significant explanatory contributions of the linear time trends of nitrate (26% of variance explained), minimum temperature (14%) and the average level of standardized FAO landings (6%). These three variables explained over 46% of the total variability between areas and separated the GSAs into four geographic groups (Fig. 1). The environment in the first geographic group (group A), including the Adriatic and Ionian Seas, displayed low increase in nitrates (average slope = 0.1), low minimum temperatures (6.2°C) , and high FAO landings (0.46 t.km-2); concomitantly all but two functional groups increased. The second group of GSAs (group B), spanning the Tyrrhenian Sea and the straight of Sicily, was associated with stable nitrates (average slope = -0.02), high minimum temperatures (12.75 °C), and low FAO landing (0.12 t.km-2). In this group the biomass of all FGs increased, in particular those of demersal and benthic functional groups. In the third geographic group (group C), made up of enclosed bays and the Balearic Islands in which the biomass of most FGs decreased slightly, the near bottom environment was characterized by a small decrease in nitrates (average slope = -0.05), low minimum temperatures (9.15°C) and medium FAO landings (0.34 t.km-2). The functional group biomass changes (decrease in pelagic FGs and increase in benthic FGs) in the fourth geographic group (Western areas; group D) were accompanied by stable time trends in nitrates (average time trend = -0.01), high minimum temperatures (11.18°C), and low FAO landings (0.12 t.km-2).

4. Conclusions/Discussion

This study provides evidence that the Mediterranean fish communities changed over the last two decades. The potential causes of changes agree with those reported in the literature: local environmental variables sensitive to oceanographic features such as temperature and nitrates (a proxy of terrestrial inputs) as well as landings (i.e. exploitation levels). The study presents an objective way for grouping fish species into functional groups which is a first step towards a mechanistic understanding of Mediterranean marine food webs. It is also a contribution to the Marine Strategy

Framework Directive as it provides a method to define functional groups of species to assess food web indicators.

5. Acknowledgements

We would like to thank the MEDITS crews that participated to the scientific surveys.

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Characterising spatial and temporal patterns of species biomass distributions in landings from the Mediterrenan and Black Sea

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Abstract

We fitted species abundance distributions to landings data from the Mediterranean and Black Sea for the period 1970 to 2013 to explore the impact of fishing on marine communities. The results show that the species abundance distributions of landings have become more right skewed over the last five decades due to a spreading of fishing across a wider range of species. At the same time total landings have decreased in the northern part of the Mediterranean Sea and increased in the southern part.
Keywords: SAD, macroecology

1. Introduction

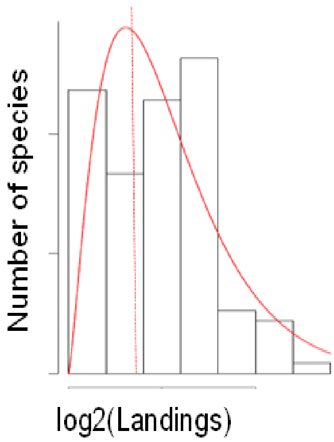
Since the early 1970s, date at which the systematic reporting of landings started, the number of exploited species has increased in the Mediterranean and Black Sea (Tsikliras et al., 2015). Over the same period the mean trophic level of landings decreased in the eastern areas including the Black Sea, remained stable in the central part, while it recovered in recent years in the western most areas(Tsikliras et al., 2015). At the stock level, over the last two decades exploitation rates of many fish stocks in the Mediterranean Sea have increased while smaller and smaller fish are being exploited (Vasilakopoulos et al., 2014). In addition to the assessed stocks it has been predicted that about 98% of unassessed stocks might be overexploited, i.e. being fished with fishing mortalities F>Fmsy (Osio et al., 2015). Thus fishing has profoundly modified assemblages in the Mediterranean and Black Sea. Species abundance distributions (SAD) have been proposed as a way for characterising the state of natural assemblages and provide early warning signals of the effect of disturbances (Matthews and Whittaker, 2015). The SAD characterises the distribution of abundances across species in an ecological community or a sample from it where abundance can be represented by numbers or biomasses. This is a very general pattern which has been found in both animal and plant communities. Much theory has been developed in macroecology to explain the shapes of SADs, see review by Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework (McGill et al. (2007). All SADs are hollow though the actual shapes vary. Generally a community with a more right skewed distribution in which many species have low abundances and only a few higher ones is considered more disturbed than a community with a more symmetrical SAD. Various statistical models including log-normal and log-series have been used to describe SADs On the species abundance distribution in applied ecology and biodiversity management (Matthews and Whittaker, 2015). The Gambin (Gamma-binomial) model is a parsimonious model for describing empirical SADs0 (Ugland et al., 2007). It consist of i) transforming abundance data by taking the base 2 logarithm, ii) assigning the log2-values to categories, and iii) fitting a Gamma distribution to these categories. Fig. 1 (left panel) presents an example. The Gamma distribution has two parameters, shape α and rate λ. The mean is $\mu=\alpha/\lambda$. If λ is fixed to 1, the mean

is equal to α which then provides a single parameter for comparing SADs between areas and time periods (Matthews et al., 2014). In our case the fitting of Gamma distributions fixing λ=1 did no converge. Instead the rate parameter λ was used as it informs on the symmetry of the distribution. Small values of λ mean the species biomass distribution is broad, with proportionally more species with smaller landings, while values around 1 mean a more symmetrical shape and values larger than 1 indicate proportionally more species with large landings.
In this study we fitted the Gambin SAD model to FAO landings time series from the Mediterranean and Black Sea. There has been much debate whether landings data inform on underlying abundances (Pauly et al., 2013). Luckily, due to the biological, social and economic characteristics of the Mediterranean fisheries a specific management framework has been put in place by the European Commission(EC, 2006). This framework combines effort controls with restrictions on gears, minimum landing size and various spatial management measures. As a result landings information should reflect, at least to some degree, the structure of the exploited assemblages. Even if landings data did not represent assemblage changes, changes in landings SAD should inform on changes in fishing pressure patterns.

2. Material and methods

The landings data set consists of the "GFCM (Mediterranean and Black Sea) capture production" data set by species or group for the period 1970-2013 which was downloaded from the FAO web site http://www.fao.org/fishery/statistics/software/fishstatj/en. Two data sets were prepared, one for total marine landings (all species landings hereafter) and one for demersal landings only. To smooth interannual variations the data was averaged for 2-year periods. To overcome at least partially the problem of landings being recorded over time more and more to the species level, landings <1 t were removed.

The parameters of the Gambin model were estimated by maximum likelihood using the MASS package in R. To ensure the λ parameter represented true changes in the distribution of landings across species, species landings per year were standardised to the same total for all years and areas. The temporal trajectories of estimated λ values were compared to those of total landings (sum across species). For this both time series were normalised. To characterise the joint trajectories, each year was coded by the quadrant of the relative positions (see Fig. 1right). The quadrants were then plotted on maps.



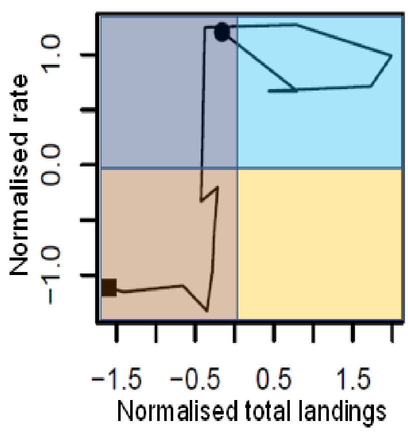


Fig. 1 *Left: Example species abundance distribution with fitted Gambin model; vertical line represents α. Right: Characterisation of joint trajectories of normalised rate λ and normalised total landings using quadrants. The dot indicates the start of the time series and the rectangle the end.*

3. Results

The Gambin model described the SAD for all species landings rather well for most years (not shown). Most distributions were unimodal. In contrast, SADs for only demersal landings were more often bimodal and the Gambin fitting did not always converge. This was caused by the bimodal distributions corresponding to the presence of two groups of demersal species, those with larger landings and those with fewer landings. This could be the result of different gears targeting different subgroups.

The estimated λ values representing the rate of the SAD for all species landings decreased in all divisions between 1970 and 1980 and remained generally stable thereafter, except for the gulf of Lions and Sardinia where is increased again (Fig. 2). At the same time the number of recorded species increased. This means that the over time the landings consisted of more species and were more evenly spread across species. For demersal landings only, λ, total amount and number of species showed time trends similar patterns to those of all species landings (not shown).

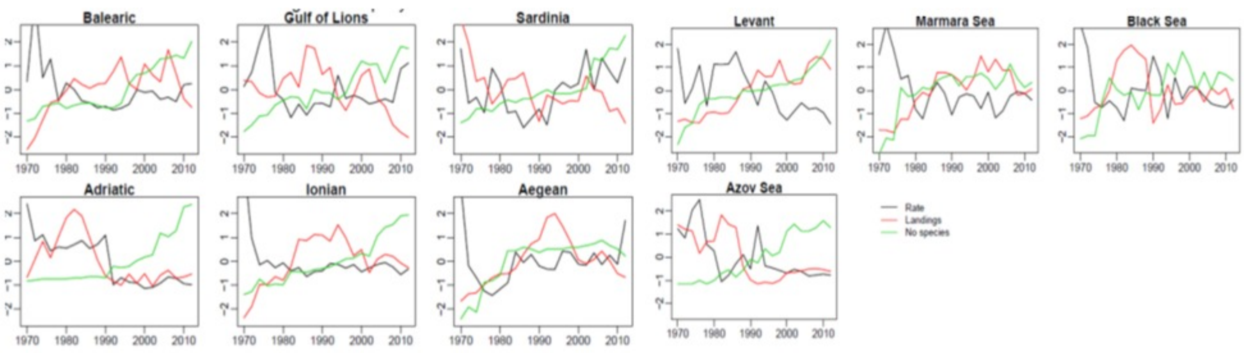


***Fig 2**. Results for all species data set. Normalised time series of SAD λ-parameter estimates (black), and summed landings (red) and number of species (green) by FAO division for the Mediterranean Sea.*

Considering spatial patterns during the period 1980-2013, in the early 1980s λ was high and landings low in most divisions indicating targeted exploitation of fewer species (dark blue in Fig. 3left), except the northern shores of the western part, and the Azov Sea where landings were high (light blue in Fig. 3). In the early 1990s the situation is more variable across divisions. At the end of the time series landings are low in all divisions except the Levant and landings (Fig 3). Rate λ values indicate a relatively higher concentration on fewer species in the western part of the Mediterranean Sea and the Aegean Sea compared to the other areas (dark blue in Fig 3). Similar patterns and changes were observed considering demersal landings only.

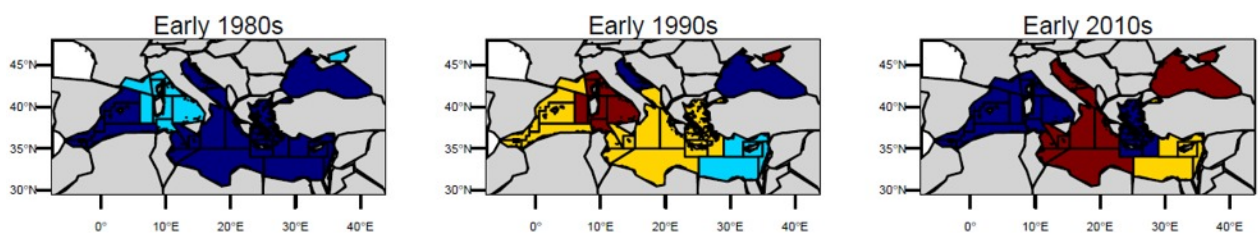


***Fig. 3.** Maps for all species data set. Joint relative value of λ estimates and total landings by FAO divsision.*

4. Conclusions

We found that the species biomass distributions of landings in the Mediterranean and Black Sea have changed over the last four decades. In the 1980s a spreading of fishing exploitation more evenly across a wider range of species was observed followed by a decrease in total landings and an increased dominance by fewer species in the western part but no the eastern part and the Black Sea by the early 2010s. If landings reflect underlying assemblage patterns, for the eastern part this might imply a more even distribution of biomass across species in recent years and stronger dominance in the western part. In addition to fishing, changing climate conditions have also modified community composition across the Mediterranean, and favoured the introduction of non-indigenous species (see overview in mpacts of climate change on European marine ecosystems: Observations, expectations and indicators</title><secondary-title>Journal of Experimental Marine Biology and Ecology (Philippart et al. (2011)). Certain species might have been favoured by increasing temperatures while others might have been negatively impacted (Tzanatos et al., 2014). Such climate effects would have contributed to shift community SADs to the left by increasing the number of less abundant species.

5. Acknowledgements

This study received funding from the European Union Seventh Framework Programme project Perseus under grant agreement number 287600.

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Effects of deep water formation processes in the population dynamics of the commercial deep-sea shrimp *Aristeus antennatus*

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Abstract

The relationship between the occurrence of deep cascading and open-sea convection events in the north-western Mediterranean and the population dynamics and recruitment processes of the deep-sea shrimp Aristeus antennatus was investigated. Continuous measurements collected during the last decade by instrumented moorings were analysed and compared with landings from the main fishing harbours. Enhanced recruitments to the fisheries were observed 3 years after the deep cascading events of 1999 and 2005, in agreement with the Company et al. (2008) conceptual model. However, successive enhanced recruitments have been occurring annually since 2008, which seem to be favoured by deep open-sea convection.
Keywords: cascading, open-sea convection, natural pressures, recruitment, fisheries.

1. Introduction

Previous studies in the north-western Mediterranean by Company et al. (2008) indicated that major dense shelf water cascading events, a recurrent oceanographic process affecting this region, influences the *Aristeus antennatus* deep-sea shrimp fisheries. Strong downslope currents associated with episodic intense cascading events displace the population from the fishing grounds, producing a temporary fishery collapse. However, nutritive particles brought by cascading waters to deep regions cause an enhancement of its recruitment process 3 years after and an increase of total landings during the following years. Following these previous findings, a specific monitoring of the occurrence of major deep water formation events in the north-western Mediterranean was conducted to determine the temporal evolution of the population structure (adult vs juvenile individuals) of *Aristeus antennatus* linked to this natural pressure. The final goal and motivation of this study is to combine both oceanographic and fishery knowledge to contribute to the implementation of a long-term Fishery Management Plan of this commercial species in the Palamós harbour. This management plan could be used a model for other fishing harbours that depend largely on this living resource to ensure the sustainability of this deep-sea fishery in the north-western Mediterranean waters.

2. Materials and methods

As part of the LIONEX experiment oceanographic data acquisition from two deep-sea instrumented moorings deployed in the north-western Mediterranean margin was carried out (Fig. 1). These moorings were previously deployed in the frame of other research initiatives, providing long-term time series of deep-water properties for more than a decade. All the lines were equipped with near-bottom current meters and conductivity-temperature-depth (CTD) sensors that allow assessin the occurrence of deep cascading and open-sea convection events.

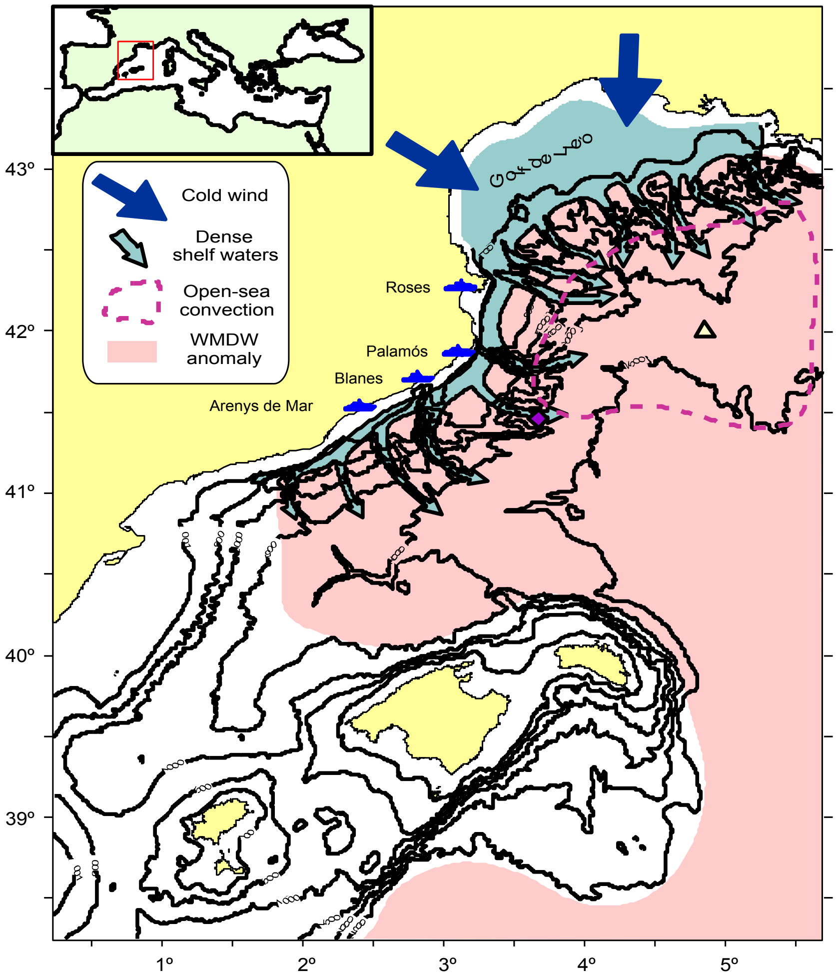

Fig.1 *Map of the north-western Mediterranean showing a schematic representation of the dense shelf water cascading phenomenon, the region influenced by the open-sea convection, and the area that was affected by the major 2005 cascading and convection event that caused a thermohaline and turbidity anomaly in the Western Mediterranean Deep Water (WMDW). The blue ships represent the major fishing harbors of this area and the symbols represent the position of the different deep-sea moorings available in the region: purple diamond: HydroChanges; yellow triangle: LION; green square: FOFA (see text for details).*

One mooring is located at 1900 m depth on the Catalan continental rise (purple diamond in Fig. 1) and it has been maintained since September 2003 as part of the HydroChanges long-term monitoring program. A second mooring has been deployed at 2300 m depth on the Gulf of Lions continental rise (LION, yellow triangle in Fig. 1) since September 2007. This second line extended from the seafloor to 150 m below sea surface and allows capturing with detail the deep water formation by open-sea convection. Collected time series have been analyzed together with the information provided by the daily landings of commercial species in the northern Catalan fishing harbors (blue ships in Fig. 1), focusing on the temporal evolution of the blue and red shrimp *Aristeus antennatus* population. The annual recruitment of the species was inferred from the landings, in particular from the different sales classes (small vs. large individuals) and the relationship weight/sales class/age shown in Company et al. (2008).

3. Results and Discussion

Figure 2 shows the time series of potential temperature and salinity measurements collected by the HydroChanges and LION long-term mooring deployments. Although the mooring lines could not be retrieved in few occasions, the combination of both records provides an almost complete monitoring of the north-western Mediterranean deep-water hydrodynamics and thermohaline properties since late 2003.

During the last decade, this region has been affected by multiple dense water formation events reaching the deep basin (Fig. 2). Winter 2004 did not generate deep dense waters, but in winter 2005 a major cascading and convection event caused an abrupt change in the properties of the Western Mediterranean Deep Water (WMDW). The convection process could be identified in the time series by an increase in temperature and salinity, while the cascading process generated a subsequent drop of these conservative water properties (Font el al., 2007). The signal of this change in the WMDW still remains at present as an effect of what has been named the Western Mediterranean Transition (WMT) (see Font et al. (2009) for details). Following the 2005 convection and cascading events, in winter 2006 a similar succession of events occurred, but with a smaller strength. Winter 2007 and 2008 did not generate dense waters able to reach the deep basin, but during the following winters (2009, 2010 and 2011) deep convection did occur, as revealed by the successive sharp increases of temperature and salinity (Fig. 2). In winter 2012, deep convection was accompanied by a deep cascading event (Durrieu de Madron et al., 2013), and the same happened in winter 2103, but with a much smaller strength (reproducing the pattern of two consecutive deep cascading events observed 7 years before, being the second less intense). It is worth to note that the preceding deep cascading events happened in winter 1999 and 2000 (Bethoux et al 2002; Puig et al., 2013), therefore showing a recurrence interval of 6-7 years. Winter 2014 did not generate deep dense waters (Fig. 2).

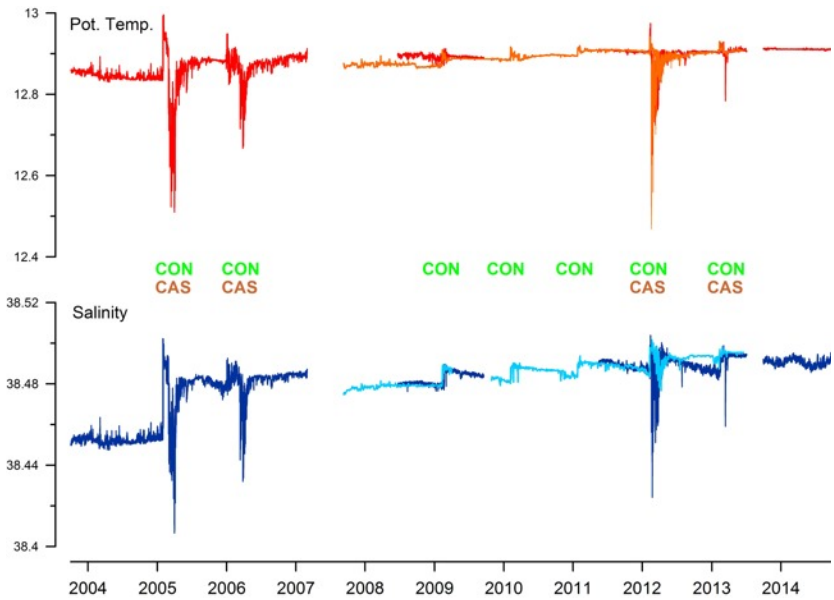

Fig. 2. *Time series of potential temperature and salinity measured near the bottom at the HydroChanges site (red and deep blue lines, 1900 m depth) and LION site (orange and pale blue lines, 2500 m depth) that illustrate the succession of deep dense water formation events that reached the basin, only by open-sea convection (CON) or combined with dense shelf water cascading (CAS).*

Daily landings of *Aristeus antennatus* were obtained from the major fishing harbours of the study regions since 2001 (Fig. 3), when the fishermen associations adopted and automatic system to archive their landings. These time series show a peak in the landings of shrimp juveniles in 2002, which suggests an enhanced recruitment of the population following the deep cascading of 1999. A peak of juvenile's landings can also be identified in 2008, which follows the 2005 cascading event (Fig. 2). These peaks confirm the hypothesis proposed by Company et al. (2008) that nutritive particles brought by cascading waters to deep regions cause an enhancement of this species' recruitment process and an increase of its total landings 3 years after. However, particularly high landings of juveniles were observed almost every year after 2008, which suggests a second controlling factor of the population dynamics of this species. The only exception to this landing pattern was observed after winter 2012, associated with the flushing of the population during the strong cascading event that provoked a temporary collapse of the landings. Such high levels of recruitment since 2008 could be an effect of the WMT (associated with the new properties of the WMDW after the anomalous winter 2005) or a response to the successive open-sea deep convection events that have characterized this region since 2009, which could have played a role maintaining favourable conditions on the basin seafloor to assure a higher larval survival during the settlement of this species after their pelagic stage.

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Seagrass distribution patterns and ecological quality status for the evaluation of GEnS under MSFD: comparative case studies in the SES

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Abstract
In the South European Seas (SES) several species of seagrass (marine Angiosperms) are present. Most of them are habitat creating species, vulnerable to anthropogenic pressures. Their distribution pattern and phenology (e.g. shoot density, leaf length) are already used for the evaluation of the environmental quality, during the implementation of the Habitat Directive (HD) and the Water Framework Directive (WFD). Many biotic indices are already in use and some of them could be used for the evaluation of the Good Environmental Status (GEnS) during the implementation of the Marine Strategy Directive (MSFD).
Keywords: MSFD, GEnS, Mediterranean Sea, Black Sea, seagrass indicators

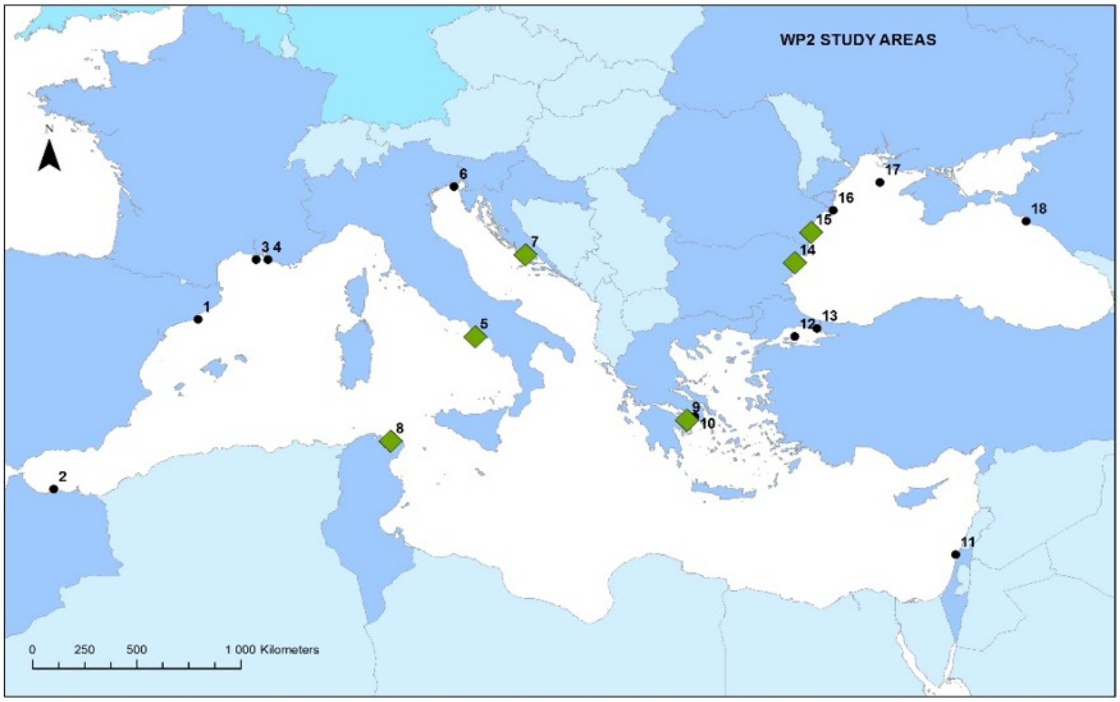
1. Introduction

PERSEUS project gave the opportunity to compare the distribution pattern and ecological status of seagrass meadows in 6 different case study areas of the SES. In the Mediterranean Sea the species *Posidonia oceanica* and *Cymodocea nodosa* were studied, while in and in the Black Sea the study focused on the species *Zostera noltei* and *Zostera marina*.
Although the species are different their ecological role in the SES presents some interesting analogies. In the open Mediterranean coasts *P. oceanica* is the endemic, emblematic and habitat crating species, replaced by *C. nodosa* in the shallow inlets and bays. In the Black Sea the species *Z. marina* and *Z. noltei*, which are rare in the Mediterranean, are the dominant seagrasses. The first species occur in the open Black Sea coasts and the second one in the shallow inlets and bays, usually under low salinity conditions (e.g. river mouths). Mixed meadows are found in semi-opened coastal areas at depth of 3-5m.

The aim of the study was to compare the actual distribution pattern with historical maps or other documents, to detect the eventual temporal changes (if any) and try to distinguish the changes due to human activities from the changes due to natural shifting of the environmental conditions.

2. Materials and methods

Field work was carried out in six PERSEUS study areas (Figure 1). In most of the cases visual observations and sampling of seagrass specimens was carried by SCUBA diving. In parallel side scan sonar data and/or satellite images were used for mapping of the seagrass meadows. The results were compared with historical maps and/or bibliographic information.



Barcelona (1), Mediterranean coastal area of Morocco (2), Rhone River and Marseilles (3-4), Naples (5), Northern Adriatic (6), Southern Croatia (7), Gulf of Tunis (8), Saronikos gulf and Athens (9-10), Haifa (11), Sea of Marmara and Istanbul (12-13), Varna (14), Costanza and Danube mouths (15-16), North-western Black Sea and Sevastopol bay (17), Gelendzhik (18)

***Fig. 1**. Seagrass study areas in the framework of PERSEUS*
Gulf of Naples (5), Southern Croatia (7), Gulf of Tunis (8) Saronikos Gulf (9)
Burgas Bay (14), Magnalia area (15)

3. Results

3.1 Distribution patterns and anthropogenic pressures

As far as the Mediterranean Sea is concerned the results of the present study showed that in small scale (e.g. on the Tunisian “Sidi Rais” Posidonia reef barrier) the *P. oceanica* meadow is rapidly and clearly regressing locally, under anthropogenic pressure (e.g. fishing activity and sewage discharges). However, at a larger scale (e.g. the meadows of Saronikos Gulf in Greece, of Split area in Croatia and in Ischia Island in Italy) it is difficult to make the difference between anthropogenic and natural regressions of *P. oceanica* meadows. Based on the available historical data in the studied areas, no global regression trend of *P. oceanica* was observed during the last 2-3 decades. It is worth to note that in contrast with *P. oceanica* meadows, which seems to be rather stable, the meadows *Z. marina* which were reported in the first decades of the 20th century as common habitat in the Mediterranean coasts are nowadays very rare, located near (or even only inside) the lagoons of the Western Mediterranean and the Adriatic.

The second species *C. nodosa*, studied in a typical Mediterranean gulf (Saronikos Gulf in Greece), presents an interesting distribution pattern: 1) the “pioneer” pattern observed in the open (outer) part of the Saronikos Gulf where *C. nodosa* usually covers the free space of high hydrodynamic conditions between the coastline and the meadows of *P. oceanica*, starting at the depth of 3-5 meters and 2) the “climax” pattern observed in the inner part of the gulf, where *P. oceanica* is absent. Although the two patterns concern the same species the first one is ephemerus due to natural stress, thus, not suitable to reflect anthropogenic pressures. The second one is naturally stable habitat, thus, very suitable to reflect anthropogenic stress and specific biotic indices have been developed for this purpose.

As far as the Black Sea is concerned, the dominant seagrasses in the Bulgarian Burgas Bay study area were *Z. marina* and *Z. noltei*. The later was the only species available in the Romanian “Magnalia” study area.

Over the last 45 years the surface of *Z. noltei* meadows in Romania reached a 95% decrease. Near-extinction of the species and habitat occurred during the Black Sea eutrophication maximum (1980s-90s), coupled with earlier large-scale anthropogenic habitat destruction (hydrotechnical works) and natural extreme events (extreme winter storms with ice scour). Compared with historical data, the actual status shows meadow fragmentation, reduced depth distribution, reduced cover and leaf length, reduced diversity of associated communities. At present the status of *Z. noltei* meadows in Romania is stable and a trend of slow increase can be maintained if present environmental conditions are maintained and proper management measures enforced.

In the western part, along the Bulgarian Black Sea coast data confirmed seagrasses distribution as described earlier by Petrova-Karadjova (1982), meaning that no significant degradation of these habitats occurred during 1980s, the period of increased eutrophication impact in the area. However, pronounced long-term trends in distribution cannot be identified due to the lack of previous geographical maps for reliable comparison.

3.2 Integration between HD, WFD and MSFD implementation

There is a common understanding that the objectives of the HD (protect, maintain or restore at Favorable Conservation Status of species and habitats of Community importance), the WFD (reach/maintain Good Environmental Quality Status based on Biological Quality Elements) and the functional ecosystem approach of the MSFD (focused in reaching/maintaining GEnS based on 11 descriptors), aim to achieve similar final goals. Further integration is needed to obtaining synergies. Basis for successful integration could be a set of common indices to be used in the future monitoring programs.

In the Mediterranean Sea a number of indicators based on the dominant seagrasses have been developed calibrated and used. For *P. oceanica* the POMI index (Romero et al., 2007) was used in Spain, and the PREI index (Gobert *et al.* 2009), was used in Greece and Croatia. For *C. nodosa* the CYMOX index (Oliva *et al.,* 2012) was used in Spain and the CymoSkew index (Orfanidis *et al.* 2007) was used in Greece. The present study showed that the WFD biotic indexes based on both seagrass species reflect anthropogenic pressure in a correlated way. They are also well correlated with biotic indexes based on other Biological Quality Elements, e.g. the EEI index (Orfanidis *et al*. 2002) based on macro-algae (data not shown).

For Zostera species, currently ZoNI is the only multi-metric index in use for ecological quality assessment of coastal and estuarine systems (Garcia-Martin et al., 2013). It is based on *Z. noltei* and developed under the WFD requirements in SW Iberian Peninsula.In the Black Sea there were no calibrated indicators for EQS evaluation based on seagrasses. Thus, an original biotic index (ZonPI) has been developed and tested in the Bulgarian PERSEUS case study area. EQR values were validated against pressures data: ZonPI scores were tested against pressure scores with the values of PCA scores of each sampling station, showing significant linear correlations ($R^2 = 0.9352$, $p<0.01$), which verifies the link between pressures and resulting EQR of study areas.

4. Conclusions

Mapping of coverage or density	*P. oceanica*: Clear regression is observed only under direct human activity on the meadow (e.g. in the case study of Tunisia). In the other case studies the observed changes were not clear. In the case study of Greece and Italy the large scale pattern of the meadow is similar to the historic maps. Local differences in meadow coverage from on period to another could be attributed to factors not directly linked to human activity (e.g. seasonal development of epiphytes in the case study of Croatia). *C. nodosa & Zostera spp.*: Mapping activity on these seagrass species has been carried out. Nevertheless, the ephemerus character of *C. nodosa* & *Zostera spp.* meadows has to be taken into account.
Seagrasses as Biological Quality Elements (BQE's)	All the seagrasses have been used for the ecological quality status evaluation. Existing biotic indexes have been used successfully (e.g. POMI in Croatian case study) and the "ZonPI" a new index has been proposed and tasted in the Bulgarian case study area. Applied indexes well correlate with anthropogenic pressure gradients in the areas.

4.1 The main conclusions of the present study are included in the following Table.

4.2 Recommendations for MSFD implementation

- The seagrasses are considered as «priority habitats» in the Habitat Directive, as Biological Quality Elements in the WFD and attributes of the D1 (biodiversity), D5 (eutrophication) and D6 (seafloor integrity) in the MSFD. Thus, a combined monitoring program seems to be feasible.
- The example of the «new» EU Member States (PERSEUS partners from Bulgaria and Romania), which were obliged to implement simultaneously the three Directives is recommended to all the EU Member States in the SES.
- The «favorable conservation status» as described in the HD is not different from the «good» environmental status as described in the WFD and could be used as GEnS for the MSFD.
- Habitat mapping methods and codes are already in use for the EU Natura sites and they could be used for the needs of MSFD.
- Biotic indexes are already in use for some seagrass species (e.g. *P. oceanica* & *C. nodosa*) for the needs of the WFD monitoring. The present study showed that they could be extended to other species (e.g. *Zostera spp.*) in order to have comparable data from all the SES.
- Seagrasses, as all the plants, present intense seasonal variability. Thus, the eventual metrics to be included in the MSFD monitoring have to be chosen carefully. Some metrics (e.g. deeper limit of extension and shoot density) do not present seasonal variations and they are more adequate for the monitoring than others (e.g. leaf length, leaf surface and epiphytes).
- Reference conditions have to be established at sub-ecoregional scale (e.g. Eastern, Central & Western Mediterranean). In some cases (e.g. near river mouths) even local reference conditions are needed.

5. Acknowledgements

This research was carried out with the financial support of the EU FP7 PERSEUS project

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NIS in PERSEUS hotspot areas: Testing trends in introduction as an indicator of GES

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Abstract

Obtained data on trends in abundance and spatial distribution of non-indigenous species (NIS) contribute to filling gaps in understanding of the ecosystem response to the pressure by biological invasions. Data compilation from various sources including field work has led to the addition of: 9 new alien and cryptogenic species in Saronikos Gulf during the PERSEUS study period (10% increase)/16 new species in the Gulf of Tunis (22% increase)/ 11 new species in Haifa Bay (6.4% increase)/1 new species in Gelendzhik Bay (4% increase). No new records were noticed in Constanza and Turkish Straits. A trend analysis over five year intervals, from 1980 to the present, indicated several interesting trends: a) the rate of introductions hassignificantly increasedat all study areas after 2000. The relatively lower rate in the last 5 years is attributed to delay in reporting new findings; b) the rate is higher in the Mediterranean areas than in the Black Sea areas; c) the low rate noticed in the 1990-94 period in most areas coincides with a low Sea Surface Temperature observed in 1993

Keywords: alien species, spatial distribution, trends

1. Introduction

The rapid globalisation and increasing trends of trade, travel, and transport in recent decades have accelerated marine biological invasions (Hulme, 2009).

In Europe, besides the EU Biodiversity Strategy Target 5 (EC, 2011), both MSFD and WFD have recently included «Non Indigenous species» among indicators required for assessing /setting the qualitative target which is Good Environmental Status (GES). The MSFD Committee (Art. 25 of the MSFD) discussed and concluded an approach and an outline for the process of a review and possible revision of the Commission Decision 2010/477/EU on GES criteria and of MSFD Annex III (see Committee/07/2013/03rev for details). Moreover, the Regulation No 1143/2014/EU, establishes rules to prevent, minimise and mitigate the adverse impact on biodiversity of the intentional and unintentional introduction and spread of NIS within the EU.

Due to the lack of data on impacts of most of the introduced species in European Seas, the impacts of invasions are often inferred from distribution data under the assumption that the more abundant the alien species, the more severe the impact (Vila et al., 2010).

The aim of this work was to perform species presence inventories or number of species encountered in widely spread locations in the Mediterranean and the Black Sea (selected PERSEUS areas). These inventories in PERSEUS 'hot spot' areas could be considered as surrogates of species abundance and of the level of invasiveness. Temporal trends in introduction of NIS, particularly invasive ones,will be tested as potential indicators (MSFD criterion 2.1), in relation to the main vectors and pathways of spreading of such species.

2. Materials and methods

The trends in new NIS records (including alien and cryptogenic species) is used here as a proxy of the trends of the invasive marine alien species (IAS). Trends in New species introductions in selected PERSEUS areas were investigated. The study areas included: Gulf of Tunis,Saronikos Gulf (wider area of Peiraias port), Haifa Bay (wider area of Haifa port), Constanza Bay, Gelendzhik Bay,and the Turkish Straits System. Figure 1 depicts the map of the study areas.

The first collection/sighting date for every species in each area was archived for all the aforementioned areas. Data was drawn from literature and from additional sampling carried out in the framework of PERSEUS. Main sources were the HCMR offline database enriched with finding from grey literature as provided by the local partners and new findings collected in the course of rapid assessment and other types of surveys (Tunis Gulf, Haifa Bay, Saronikos Gulf, Turkish Straits, Gelendzhik Bay). For all aforementioned risk areas, trends per year were calculated for the period 1980 to 2014 at 5 year intervals.

***Fig 1**.Map of study areas for trends in NIS(8: Tunis Gulf; 9-10: Saronikos Gulf; 11: Haifa Bay, 12-13: Turkish Straits, 15: Constanza Bay; 18: Gelendzhik Bay)*

3. Results

The Gulf of Tunisia hosts 89 alien and cryptogenic species (Figure 2), 15 of which are classified as invasive. 24 species were reported before 1980. The maximumrate of introductions, 4.2 species per year, was found in the 2010-2014 period.Saronikos Gulf hosts 98 NIS species (Figure 2), 17 of which were reported before 1980. Maximum rate of introductions was7 species/year in the 2005-2009 period. Haifa Bay hosts approximately 200Alien and cryptogenic species (all taxa), 28 of which are classified as invasive (Figure 2). Based ona long history of observations in in the area, the rate of introduction per year appears to have increased from 2 new records per year in the early 1980s to approximately 6 new species per year in 2009-2014 period (Figure 2). During the 2013 reef survey carried out in the framework of PERSEUS, 11 species were added to the list, all are known as invasives in the Levantine but were not reported from the area in the past. The Turkish Straits System hosts 90 NIS, 22 of which were introduced before 1980. Maximum rate of introductions (3 species per year) was in the 2005-2009 period (Figure 2). Constanza Gulf hosts 25 NIS**.** Usually, every 5-6 years, a new alien species is recorded at the Romanian littoral (Skolka & Preda, 2010), a phenomenon in direct connection with the commercial trades performed in the coastal zone. Finally, Gelendzhik Bay hosts26 alien and cryptogenic species (macrophytes excluded). Until 1995 only 5 introduced species were known from the area. The rate of introductions has increased exponentially reaching a max of 2.2 species per year) in the 2005-2009 period (Figure 2).

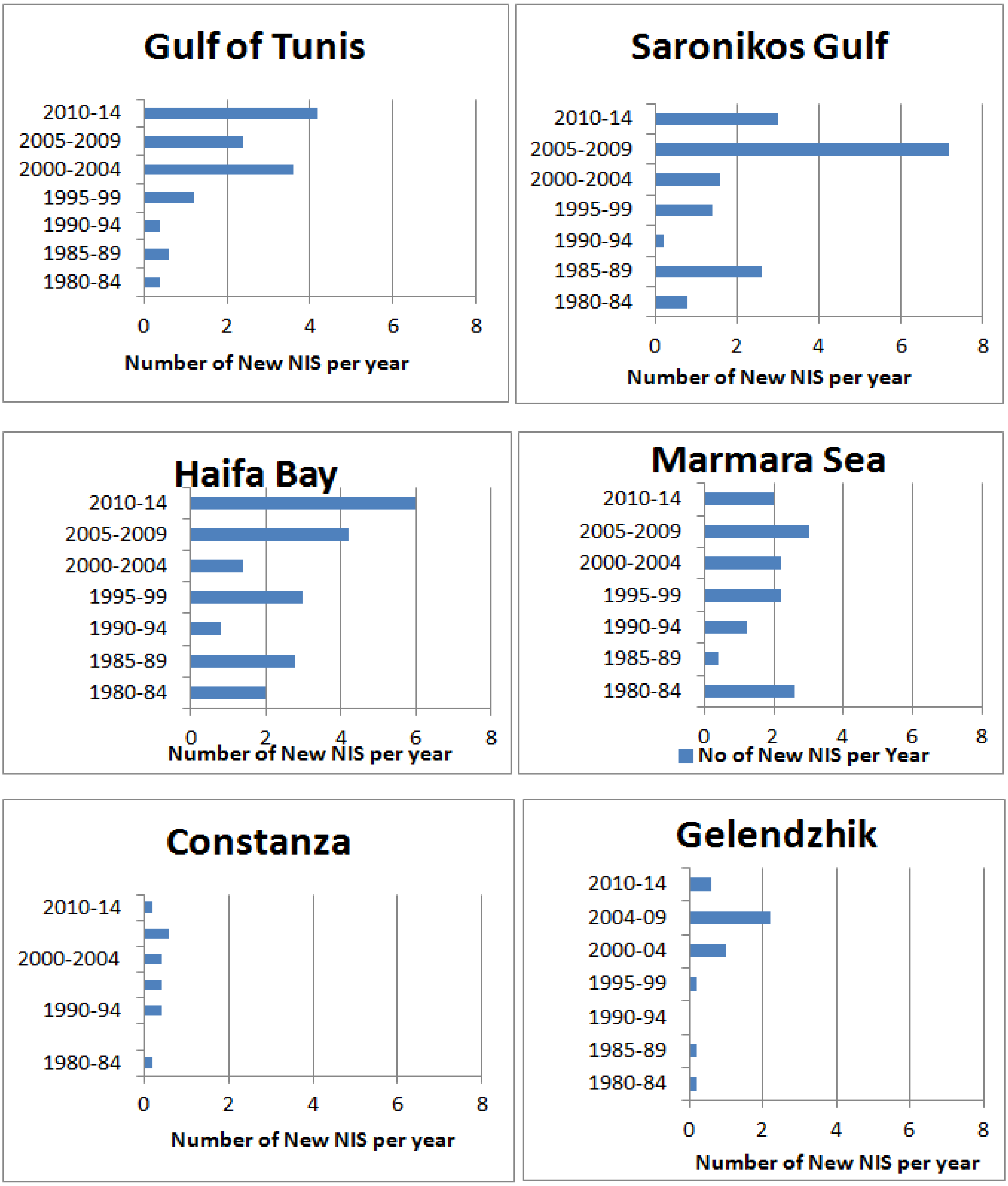

***Fig. 2**: Rate of introduction of New NIS species in the study areas*

4. Conclusions/Discussion

The Marine Strategy Framework Directive (MSFD 2008/56/EC) rates bio-invasion *among serious threats to biodiversity and ecosystem health. The MSFD* requires specific criteria to be applied from Member States in order to achieve *Good Environmental Status* (GES) in European seas by 2020, which presupposes good knowledge of the impact of invasion on native ecosystems and key ecosystem services.

Our results revealed an increasing trend in NIS introductions at all study areas after 2000. The relatively lower rate in the last 5 years is attributed to delay in reporting new findings. The rate in NIS introductions is higher in the Mediterranean areas than in the Black Sea areas.The fact that there was a strong increase in the number of recorded NIS in most regions, although the vectors in the different regions are very different, suggests that an external driving force may be behind this trend. The most suspected culprit is ocean warming drive by climate change, which can facilitate not the arrival but the successful establishment of new thermophilic arrivals. Ocean warming was exceptionally strong in the Levant in the past few decades (Sisma- Ventura*et al*., 2014).The low rate noticed in the 1990-94 period in most areas coincides with a low Sea Surface Temperature observed in 1993 (Raitsos et al., 2010).

From the results of this study it is inferred that trends of new introductions of NIS is a reliable measure for assessing GES although its usefulness is hampered by scarcity of data in most areas. Current results are only indicative. In Saronikos Gulf, where the trend of new NIS appears to bemaximum, this could be due to concerted efforts to report them and the existence of a national network (ELNAIS) (Zenetos et al., 2015). It is suggested that national networks reporting and registering NIS are developed within each country, by engaging all relevant human sources including CITIZEN SCIENTISTS.

As the impact of most NIS has not been quantified, it is suggested that hot spot areas are regularly monitored for assessing changes in the community structure and that experimental work testing impacts in a rigorous way is implementedthrough funding for research.

5. Acknowledgments

This research has been partially supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Anthropogenic impacts on deep submarine canyons of the NW Mediterranean Sea

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Abstract

We review and assess the most significant anthropogenic impacts that focus on submarine canyons in the NW Mediterranean Sea within four categories: large-sized marine litter, microplastics, emerging pollutants and physical damage of the seafloor. Our work shows the close links between high-energy oceanographic processes, such as dense shelf water cascading and storms, and the transport and accumulation of anthropogenic marine debris and contaminants to deep canyon environments. It also shows the pervasive character of seafloor disturbance by bottom trawling in those environments.
Keywords: Marine litter, microplastics, perfluoroalkyl compounds, bottom trawling.

1. Introduction

Submarine canyons are seafloor geomorphic features connecting the shallow coastal ocean to the deep continental margin and basin. Often considered biodiversity hotspots (e.g. De Leo et al., 2010), canyons have been identified as preferential pathways for dense water, sediment and organic matter transfers to the deep ocean (Nittrouer and Wright, 1994; Canals et al., 2006). They have also been pointed out as vectors for litter and pollutants transport to the deep sea (Galgani et al., 2000; Salvadó et al., 2012; Ramírez-Llodrà et al., 2013).

In this communication, which is framed within the LIONEX experiment, we provide insights on some of the most insidious pressures and impacts observed on submarine canyons of the NW Mediterranean Sea, which are relevant for Good Environmental Status (GES) descriptors 6, 8 and 10 of the Marine Strategy Framework Directive (MSFD). Concerning objects and chemicals exotic to the marine environment, we review the origin, distribution and transport mechanisms of i) marine litter, defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (UNEP, 2009) mainly using data referred in Tubau et al. (2014); ii) microplastics in the form of fibres of rayon, polyester, polyamide and acetates, mainly using data from Woodall et al. (2014); and iii) persistent organic pollutants (POPs) including perfluoroalkyl substances (PFAS), as reported by Sànchez-Vidal et al. (2015). PFAS are extremely persistent, toxic and bioaccumulative, and are widely utilized in the manufacturing of a number of goods of daily use by consumers. Concerning seafloor integrity this contribution builds on previous work by Puig et al. (2012) and re-examines the relation between the nature of the seafloor and its disturbance by bottom trawling. This integrated analysis allows us to better understand the pivotal role of submarine canyons in conveying the anthropogenic signal to the deep, as mediated by both high-energy atmosphere-driven oceanographic processes and direct human disturbance of the seafloor.

2. Materials and methods

Marine litter was monitored using the *Liropus 2000* ROV provided by the Spanish Institute of Oceanography (IEO). *Liropus 2000* is a Super Mohawk 24 ROV rated to 2000 m water depth and equipped with three video cameras including a frontal full HD Kongsberg OE14-502A camera. Litter items were identified in 24 of the 26 dives carried out in the Cap de Creus, La Fonera and Blanes submarine canyons at depths ranging from 140 to 1731 m (Fig. 1). Relative abundance of litter objects by type, size and apparent weight, and distribution of litter in relation to depth and canyon environments (i.e. floor and flanks) were analysed.

Microplastics were identified through the analysis of the first cm of sediment cores obtained with a multicorer in the Blanes canyon at 300 and 1200 m (Fig. 1). Microplastics were extracted from the sediment and filtered prior to object identification with a Bruker IFS66 Fourier transform-infrared (FT-IR) spectrometer. Bruker's OPUS 5.5 spectroscopy software was used for measurement, processing and evaluation of the IR spectra.
PFAS were measured in sinking particles collected with Technicap PPS3/4 sequential sampling sediment traps moored at 300 and 1000 m of water depth in the Cap de Creus canyon (Fig. 1). Sinking particles were dried, spiked, extracted, centrifuged and the supernatant thus obtained transferred into a polypropylene tube prior to reconstitution and subsequent analysis of selected compounds by liquid chromatography coupled to a tandem quadrupole mass spectrometry analyser provided with an electrospray ionization source (LC–ESI–QqQ-MS/MS).

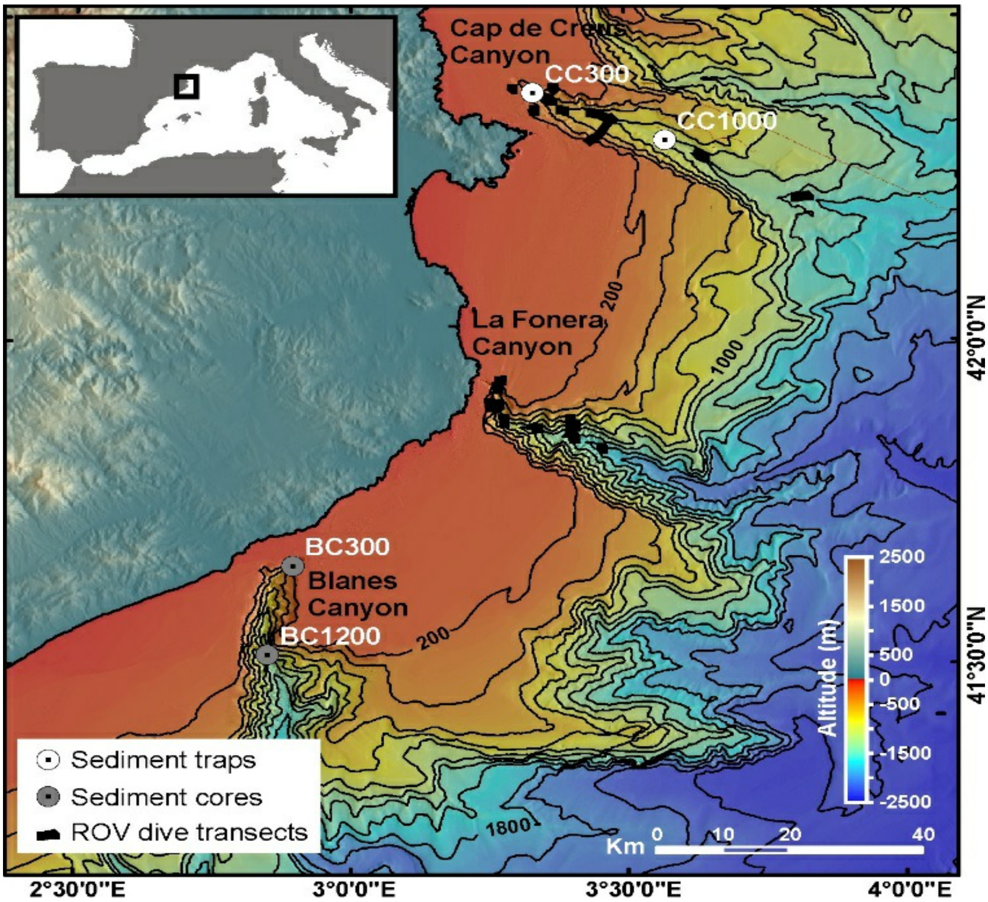

Fig.1 *Map of the study area showing ROV dives, and microplastic and PFAS sampling stations performed with sediment cores and sediment traps, respectively.*

The analysis of the large-scale modification of the seafloor relief by persistent, decades-long bottom trawling was performed through the integration and joint analysis of duly processed high-resolution multibeam bathymetry datasets obtained during several research cruises and Vessel Monitoring System (VMS) datasets provided by the Fishing Monitoring Centre of the Spanish General Secretariat of Maritime Fishing (SEGEMAR). After some filters are applied, VMS data allow knowing where the bottom trawling fleet operates and at which frequency, thus easing the analysis of possible relation between seafloor alteration and bottom fishing at the resolution of multibeam grids.

3. Results

Plastics have been found to be the dominant marine litter component (72%), followed by lost fishing gear (17%), and metal objects (8%) (Fig. 2a). La Fonera and Cap de Creus canyons show the highest mean concentrations of litter ever seen on the deep-sea floor, with 15,057 and 8,090 items per km^{-2}, respectively, and for a single dive litter, with 167,540 calculated items per km^{-2}.

Microplastics were abundant in the two sediment samples analyzed. All microplastics were fibrous in shape, commonly 2–3 mm in length and less than 0.1 mm in diameter. Plastic microfiber abundance in the sediments ranged from 25 to 60 pieces per 50 ml and mostly consisted of rayon (47% of the total number of fibres), followed by polyester (35%) and other synthetics, which included polyamides and acetates (18%) (Fig. 2b).

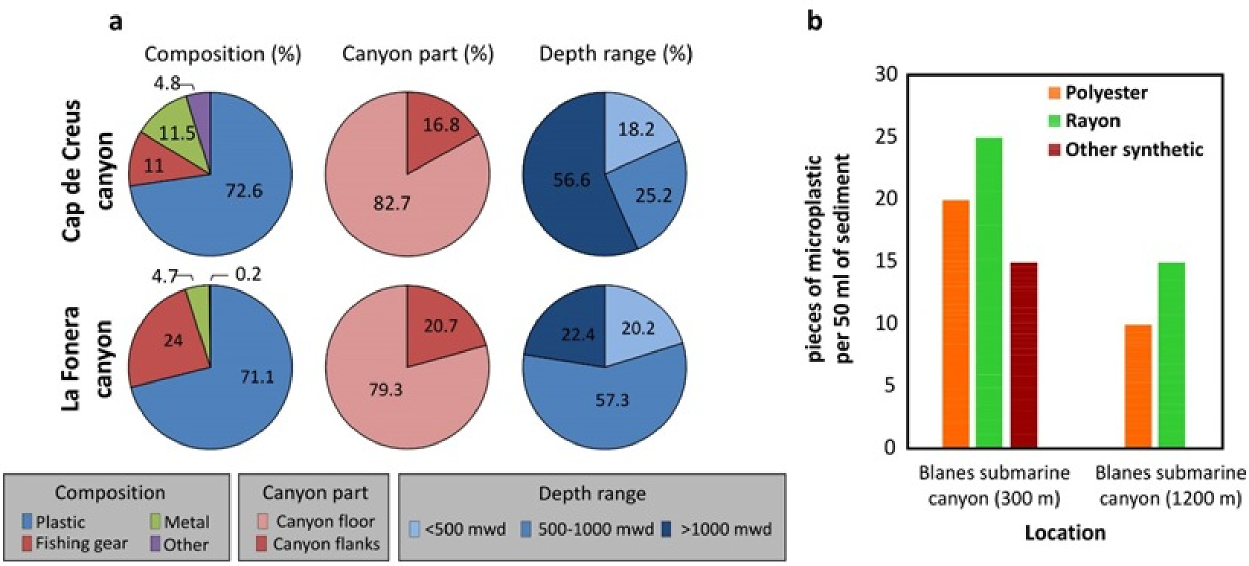

Fig.2 a) *Pie charts illustrating abundances of litter by type, canyon environment and depth range for Cap de Creus and La Fonera canyons (modified from Tubau et al., 2014).* ***b)*** *Bar chart showing the quantity and type of plastic fibres found in 50 ml of sediment sampled from 300 and 1200 m of water depth in the Blanes submarine canyon.*

We found quantifiable concentrations of PFAS, with 5 out of 21 PFAS substances detected including perfluorooctane sulfonic (PFOS), perfluorooctanoic (PFOA), perfluorononanoate (PFNA), perfluorohexanoic (PFHxA), and perfluorobutanoic (PFBA) acids. The concentration of total PFASs exceeded 10 ng g^{-1} in several samples, and the dominant PFASs was PFHxA (contributing on average a 60% of the total PFAS with 0.04-11.65 ng g^{-1}) followed by PFOS (21%, with 0.02-10.64 ng g^{-1}) and PFBA (17%, with 0.85-4.95 ng g^{-1}). PFAS fluxes increased one order of magnitude

concomitantly with the occurrence of hydrodynamic events such as eastern storms and dense shelf water cascading.
VMS data reveal that bottom trawling is recurrently performed on canyon flanks down to ~900 m depth wherever the seabed is predominantly of sedimentary character. Large-scale smoothening is clearly observed in some of the areas, where trawlers "built" a sort of contour parallel "fishing highways" or terraces extending at various levels from the canyon rim down into the canyon flank. In a way, such terraces resemble fluvial terraces as they tend to be parallel to the canyon upper edges and placed at different levels. They also represent a major, roughly 90º shift in the dominant direction of canyon flank relief-forming features, as illustrated by flank gullies running normal to the canyon rim that are progressively erased and replaced by those terraces as a result of recurrent bottom trawling along the same grounds. This is particularly the case of La Fonera canyon. However, not every place were bottom trawling is nowadays practiced displays evidence of canyon flank terracing, which may be indicative of a different nature of the seabed, a cumulated smaller trawling effort, different trawling practices or combinations of these.

4. Conclusions/Discussion

High-energy, down-canyon near-bottom flows are known to occur in the investigated submarine canyons, named, from north to south, Cap de Creus, La Fonera and Blanes canyons. These are associated to seasonal dense shelf water cascading, and severe coastal storms (see review in Canals et al., 2013), which are the most energetic hydrodynamic processes thus becoming the best candidates as main carriers of anthropogenic debris and compounds to the deep. Furthermore, bottom trawling generates daily sediment-laden gravity flows that, overall, represent large volumes (see supplementary information in Puig et al., 2012). In addition, the fact that the investigated canyons have their heads at short distance (<4 km) from the shoreline enhances their ability to trap littoral drift currents and also to convey to the deep the debris and pollutant loads they carry.

We have found litter densities in these canyons higher than elsewhere, and mostly comprised of plastic. The largest concentrations were found on canyon floors beyond 1000 m, while relatively little litter was identified in canyon walls (Fig. 2). Accordingly, we have also found large quantities of microplastics in the form of fibres in canyon floor sediments, which are high when compared to shallow water marine sediments. Concentration of PFAS in sinking particles were comparable to those found in coastal environments, which illustrates almost constant concentrations of these substances along the near-shore to deep-sea continuum and fits with their extreme persistence and long residence time once in the aquatic environment. Overall, our findings evidence that these submarine canyons are indeed preferential routes to the deep sea for anthropogenic litter and chemical pollutants. Near-bottom wind-driven flows may exert a "cleaning role" of the coastal areas carrying large amounts of pollutants to the deep margin and basin where they sink and accumulate before getting buried. Finally, bottom trawling behaves not only as a bottom disturbance mechanism that is highly relevant in some areas, like canyon flanks, but also and very likely as a stirrer for both litter and chemical pollutants temporary stored in the fishing grounds, thus easing their spreading in the ocean's interior.

5. Acknowledgements

This research has been supported by PERSEUS (FP7-OCEAN-2011-3-287600) and NUREIEV (CTM2013-44598-R) research projects, and Generalitat de Catalunya grant 2014 SGR 1068. We are in debt with the crews of IV Lluerna, RV Hespérides, RV Sarmiento de Gamboa and RV García del Cid, and with all colleagues who participated in the expeditions at sea and data analysis and interpretation including researchers at IDAEA-CSIC (Spain), Natural History Museum of London and Plymouth University (UK).

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What’s the Lifespan of Plastic Bottles in the Marine Environment?

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Abstract

Polyethylene terephthalate bottles (PETs) collected from the submarine environment of the Saronikos Gulf (Greece) were analyzed in respect to environmental degradation. A conclusive temporal indication was used as indicative to the years of presence of the PETs in the environment as debris. Using this time series for PETs collected from Saronikos Gulf, it was possible to date additional bottles that were collected from the submarine environment of the Ionian Sea. PETs seem to remain robust for at least a decade. Afterwards, a significant decrease of the native functional groups was recorded; some even disappear; or new - not typical for PET - are created.

Keywords: Litter, PET, Degradation, Seabed, Greece

1. Introduction

Plastics are ubiquitous in the marine environment, in vast quantities (*Zaikab, 2011*), consisting the major pollutant component of the world’s seas and oceans (*Law et al., 2010*), present even on the most remote areas of the planet (*Cózar et al., 2014*). The boom in the global plastic production, reaching up to 280 million tons in 2012 (*Rochman et al., 2013*) and the imprudent use of plastics in our everyday life (*Bakir et al., 2012*) elevated plastics into a major environmental threat for which no information exist regarding the lifespan of plastics in the marine environment.

Here, we investigate the degradation of plastic polyethylene terephthalate bottles (PETs) of different age that were found in the submarine environment of the Saronikos Gulf and the Ionian Sea. Our goal is to investigate their surface properties in order to gain any possible signs, which could trigger a hypothesis about the degradation process of plastics within the years of deposition in the environment. Moreover, as a secondary aim, the present study demonstrates that different types of organisms inhabit the surface of plastic bottles.

2. Materials and methods

Plastic bottles made of polyethylene terephthalate (PET) were collected from the deepest part (150-350 m) of the Saronikos Gulf (Greece) on condition that the expiration date was discernible. From a total of 509 plastic bottles, only in eight (8) colorless PETs the expiration date could be clearly viewable; corresponding in the following years: 1997, 1998, 1999, 2001, 2008, 2011, 2014. The plastic bottles were sorted and coded according to their expiration date, in two categories: the ‘90s bottles (1997, 1998, 1999) and the millennium bottles (2001, 2008, 2011, 2014). The expiration date - usually two years after production - was used as denotative to the time-period that the samples were present in the environment, including the marine.

All collected samples (PETs) were analyzed in respect to environmental degradation through the estimation of the Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR), in order to determine any possible functional groups on the surface of PETs, which could be further attributed to environmental degradation. The degraded (ER) samples were compared to a similar virgin (V) sample obtained from a supermarket, coded as 2015. Furthermore, the surface topography and roughness as well as the organisms inhabiting on the surface of PETs, were investigated and visualized under SEM. The findings of the present study were compared with the ones measured for PETs (1995i, 1998i, 2010i, 2011i) found in another sea basin i.e. Ionian Sea (Western Greece).

3. Results

The ATR-FTIR comparative spectra of the outer surface of the eroded PETs were plotted in a comparative way (*Fig. 1*). For the PET V, five main peaks are identified at wavenumbers 1715, 1245, 1100, 870, and 730 cm^{-1}, corresponding in ketones (C=O), ether aromatic (C-O), ether aliphatic (C-O), aromatic (C-H) and aromatic (C-H) bond. For PET ER, the same peaks are observed. Among the native groups of the polymer (PET), there are various that are decreasing or even disappearing and are attributed to the environmental degradation. At 1715 cm^{-1} (C=O), there is a decrease; same for 1245 cm^{-1}; at 1100 cm^{-1}, there is a decrease and in some extent the peak disappears (*Fig. 1b*); at 870 cm^{-1}, the aromatic (C-H) is disappearing, while at 730 cm^{-1}, there is a decrease and the peak almost disappears. The outer PET surface also demonstrates new groups, which are not typical for PET. These groups were observed in the samples (1997(a-b), 1998 and 1999) as follows: (a) at 620 cm^{-1} (*Fig. 1*a) a new alkyne bond (C-H) is created and (b) at 1435 cm^{-1} (*Fig. 1c*) a new alkane (C-H) bond is created as well. The environmental degradation of PETs from the Ionian Sea gave very encouraging results when compared to the ones of the Saronikos Gulf (*Fig. 2*). The two old bottles i.e. 1995i, 1998i from the Ionian Sea gave the similar patterns in the deterioration of the five main peaks at wavenumbers: 1715, 1245, 1100, 870 and 730 cm^{-1} (*Fig. 2*) as well as in the formation of the new functional groups at wavenumbers 620 and 1435 cm^{-1}.

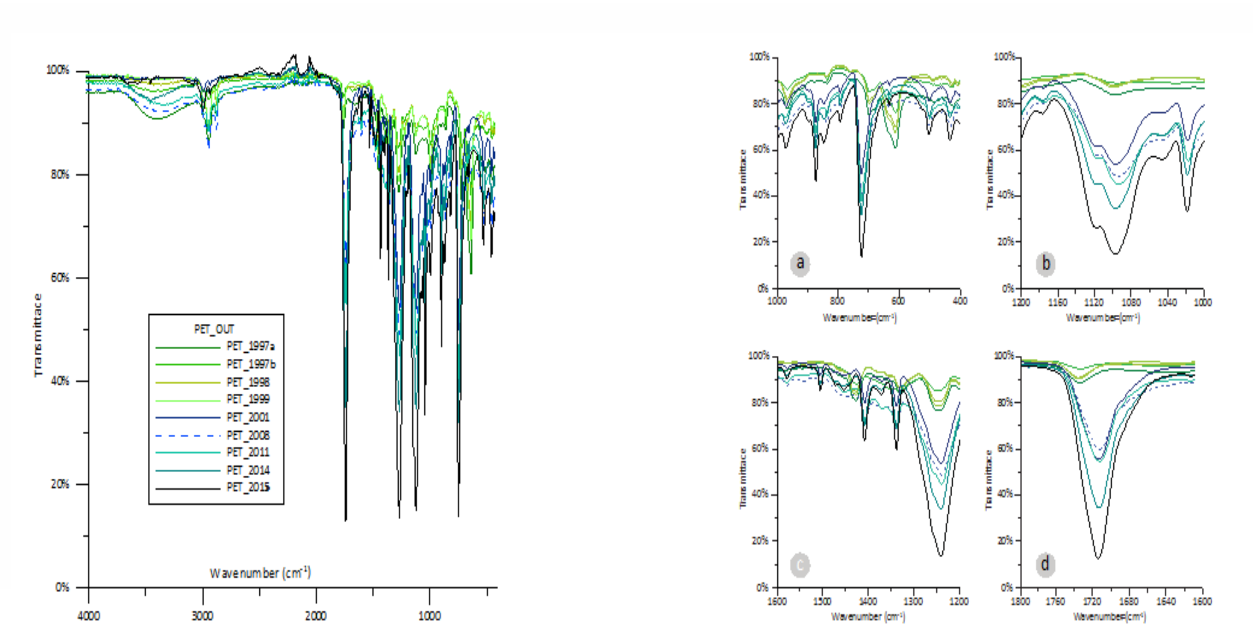

Fig .1 *ATR-FTIR comparative spectra of the outer (OUT) surface of the eroded PETs (1997(a-b), 1998, 1999, 2001, 2008, 2011, 2014) compared with a virgin (V) sample. For better visualization, enlarged excerpts of the ATR-FTIR comparative spectra are given at wavenumbers (a) 400-1000, (b) 1000-1200, (c) 1200-1600, (d) 1600-1800 cm^{-1}.*

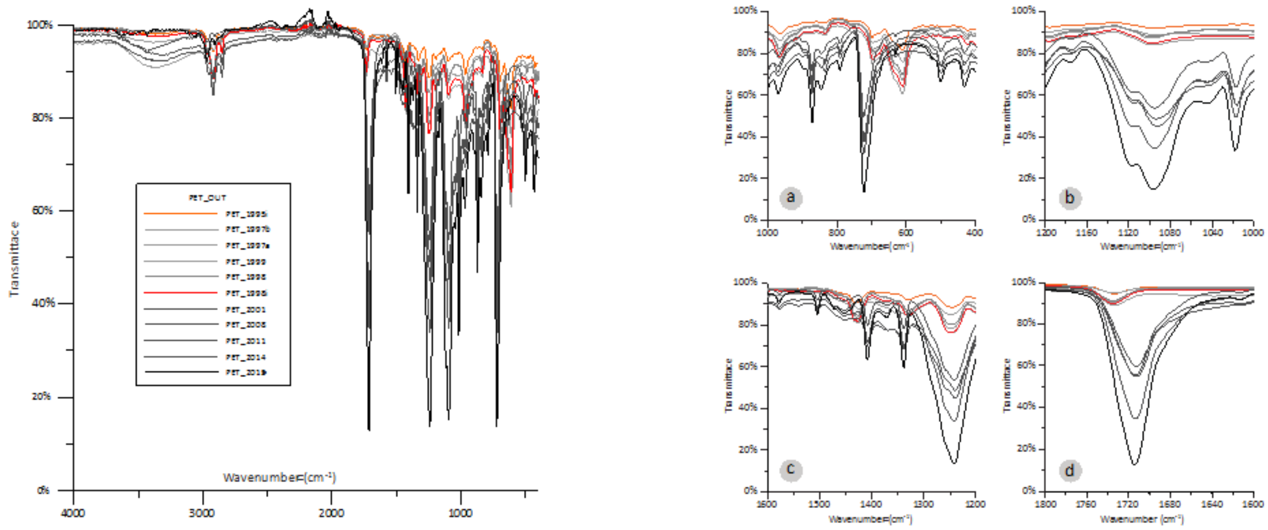

Fig. 2: *ATR-FTIR comparative spectra of the outer (OUT) surface of the eroded PETs from the Saronikos Gulf (1997(a-b), 1998, 1999, 2001, 2008, 2011, 2014) and the old samples from the Ionian Sea (1995i, 1998i) compared with a virgin (V) sample. For better visualization, enlarged excerpts of the ATR-FTIR comparative spectra are given at wavenumbers (a) 400-1000, (b) 1000-1200, (c) 1200-1600, (d) 1600-1800 cm^{-1}.*

Especially, the 1998 PET from the Ionian Sea (1998i) gave similar ATR spectra with the 1998 PET from the Saronikos Gulf. Moreover, the ATR spectra of the 1995 PET from the Ionian Sea (1995i) gave even higher deterioration when compared to the oldest PET from the Saronikos Gulf (1997), with the deterioration being significant. Moreover, the newer samples from the Ionian Sea (2010, 2011) followed the same pattern as the corresponding ones from Saronikos Gulf.

Because the samples of this study were successively rinsed with electrolyte solution and dehydrated by ethanol, as we wanted to have a clear polymer surface to investigate; microorganisms were not expected to be found. Nonetheless, strong aggregations of groups of benthic Mediterranean organisms (*Rhodophyta, foraminifera, Serpulids*) as well as microbial structures (microbial films) were found attached on clay sediment and microbial structures i.e. microbial films were found. These structures did not prevail in the samples. Nonetheless, characteristic visualizations are provided for PETs under *Fig. 3*.

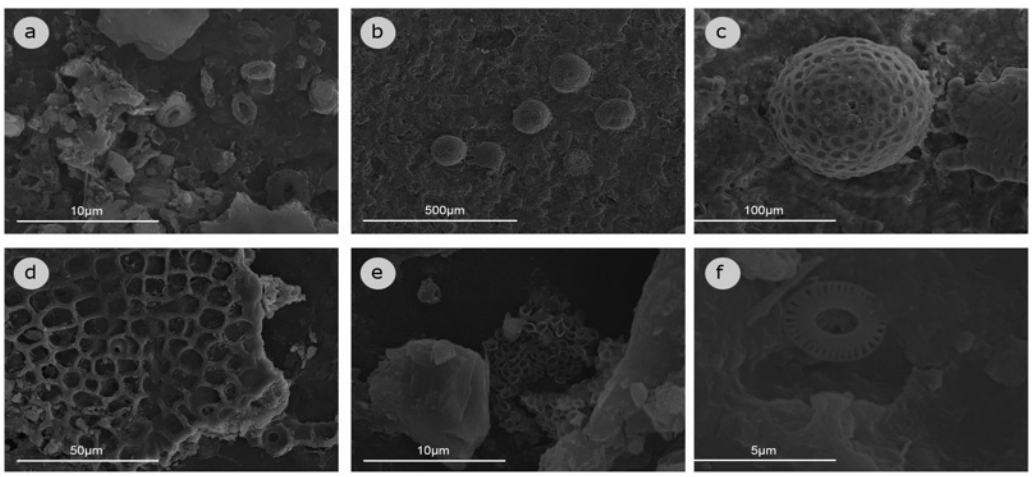

Fig. 3: *Groups of benthic organisms attached on PET bottles.*

4. Conclusions/Discussion

A conservative estimate regarding the old samples (1997 (a-b), 1998, 1999) is that they are exposed in the environment, including the marine environment, for more than a decade. When compared to the newer samples (2001, 2008, 2011, 2014), PETs seem to stay robust for more than a decade in the environment. This is corroborated by the additional groups that were created only on the surface of the older samples (1997(a-b), 1998, 1999) at wavenumbers 620 cm^{-1} (C-H) (*Fig.* 2a) and 1435 cm^{-1} ($C-H_2$) (*Fig. 2c*). It is the first time that such groups are recorded on PETs. Similar results were provided by both the Saronikos Gulf and the Ionian Sea, thus by comparing the ATR spectra of PET samples one could date PET litter bottles from different marine environments.

At the same time, no or scarce information exists regarding the life-time of the synthetic polymers in the environment or under laboratory conditions which could be used as a reference towards the comparison of the present findings. In laboratory experiments studying PET degradation, a life expectancy of PET bottles was predicted under 100% humidity of 27 (*Edge et al., 1991*) and 93 (*Allen et al., 1994*) years. Whereas Muller et al. (*2001*) in his review paper based on the above-mentioned studies predicted the general life-time of PET ranging from 16 to 48 years. At low temperatures, hydrolysis appears to be the most important degradation process. The findings of the present study show that plastics seem to follow a different pattern when stranded in the environment. Specifically, after of approx. a decade the degradation of PETs seems to be evident. Hence, the degradation of plastics in the marine environment is very subjective to the environmental conditions that are difficult to be simulated in laboratory conditions.

5. Acknowledgements

The present study was conducted within the framework of the European IP Project FP7 - PERSEUS EC Grant Agreement No 287600. C.I. has received a Ph.D. grant. Sampling in the Ionian waters was conducted within the framework of the 'DeFishGear' project IPA-Adriatic Cross Border Cooperation 2007-2013'.

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Chemical pollution in the South European Seas: methodological approaches and assessment elements

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Abstract

Chemical pollution is a known issue affecting marine ecosystems. International environmental protection frameworks are implementing ecosystem-based approaches that include dedicated sections for the assessment of contaminants in the South European Seas (SES). PERSEUS analysed the methodological approaches and assessment elements used by EU Member States in the SES within the implementation of the Marine Strategy Framework Directive (MSFD), providing a gap analysis and recommendations for the way forward. Positive efforts are made to harmonize methodological approaches between the MSFD and the Regional Sea Conventions in the SES, but there is still a lot of work to be done. Analysis indicated need for further collaboration, communication, information exchange and coordination. Harmonization of technical details is crucial for comparability of data and assessments.
Keywords: contaminants, assessment, monitoring, WFD, MSFD

1. Introduction

Contamination by chemical pollutants is one of the main environmental risks identified by PERSEUS in the South European Seas (SES). Organic chemicals and heavy metals have been found at levels of toxicological concern for marine organisms in many coastal areas. Impacts and biological effects have been observed in different species, including gastropods, mussels and seabirds (Crise et al, 2015).

The SES are complex scenarios for marine environmental protection because of the large number of EU and non-EU countries involved and the need for regional coordination in order to protect ecosystems at different scales. Three international environmental protection frameworks are implementing ecosystem-based approaches in these regions: the Marine Strategy Framework Directive (MSFD, 2008/56/EC); and the Regional Sea Conventions (RSCs) named Barcelona Convention - Mediterranean Action Plan (UNEP/MAP) and Bucharest Convention - Black Sea Commission (BSC). Within the existing ecosystem-based approaches there are dedicated sections for the assessment of contaminants. These important players have to develop collaboration among them in order to achieve a reasonable level of harmonization to guaranty that approaches will be compatible, comparable and coherent for the assessment of the environmental status of our seas.

2. Materials and methods

In this work, the approaches for the assessment of chemical pollution are compared among the existing international environmental protection frameworks in the SES, including main structures, subdivisions and detailed proposed assessment elements.

Further, based on PERSEUS analysis of the EU 'Initial Assessment' reports submitted by 10 Member States (MSFD Article 8 requirements), methodological approaches and basic assessment elements were identified, including a gap analysis performed for the MSFD Descriptor 8 (Concentrations of contaminants are at levels not giving rise to pollution effects) and Descriptor 9 (Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards). The results are compared with the progress done by PERSEUS in the study of contaminants in EU and non-EU study areas.

Finally, an analysis of assessment elements proposed by EU countries in their monitoring programs (MSFD Article 11 requirement) is performed in order to overview the progress of the implementation of MSFD regarding the assessment of chemical contaminants. This completes the gap analysis performed for the 'Initial Assessment' reports.

3. Results

For concentration of contaminants, the three management frameworks consider the measurement of hazardous substances in different matrices: water, sediment and biota. The consideration of several matrices for assessment is an asset since it provides complementary information that can improve the protection of the marine environment. The use of a single matrix should not be substitute for the others.

Contaminant in seafood is explicitly considered in MSFD and UNEP/MAP. BSC includes contamination in several commercial species (as contamination of biota) in their BSIMAP and therefore it would be feasible to carry out an assessment on contaminants in seafood. The difference between assessing contaminants in biota and seafood is that, basically, the second one considers regulatory levels based on risk assessments for human consumption, independently from the possible effects that the existing levels of contaminants could have on the biota itself.

The gap analysis of the 'Initial Assessment' reports indicated that MSFD Descriptor 8 was well documented; many methodologies were reported to be used based on available data, mainly in the coastal areas. A special issue was that appropriate monitoring programs need to be developed, for most countries, in order to cover offshore area. Regarding MSFD Descriptor 9, the main methodology used was Regulation 1881/2006, but also WFD, OSPAR and other national and/or international regulations were considered. Fig.1 includes the summary of methodological approaches and assessment elements used by 7 EU Member States in the SES according to the 'Initial Assessment' reports.

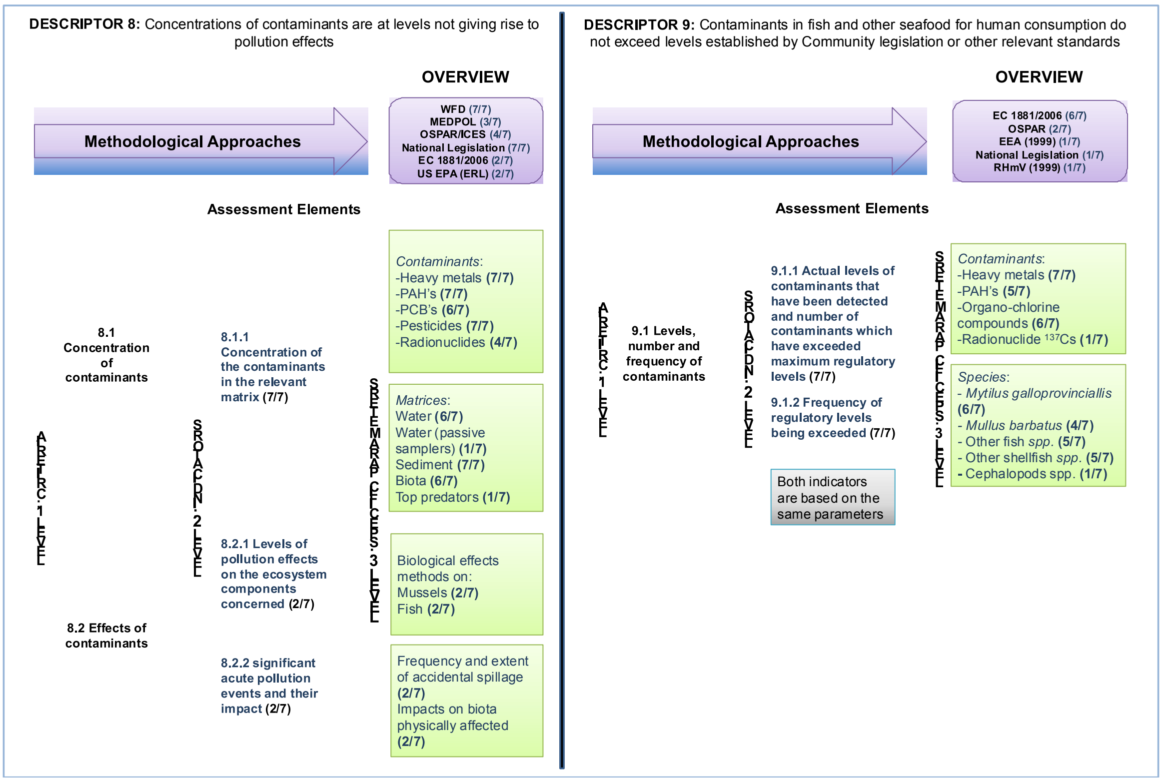

Fig.1 *Summary of methodological approaches and assessment elements used by EU Member States in their 'Initial Assessment' reports (MSFD Article 8 requirement). 7 Countries: Bulgaria, Cyprus, Greece, France, Italy, Romania and Spain.*

For Descriptor 8, substantial data on contaminants concentrations exist and several well established international methodologies are used by EU members. However, there are partial data gaps (e.g. spatial data limited to coastal areas) and a restricted number of contaminants is considered. Emerging pollutants need to be included in monitoring programs. Further, countries are using regulatory thresholds from extra-Mediterranean regions in their assessments, including OSPAR Convention and US Environmental Protection Agency, indicating the lack of regional thresholds or reference levels, particularly in sediment and biota matrices. Regarding effects indicators, some countries were not able to consider Criteria 8.2 in the assessment because of lack of data, but indicators are available to be used in the assessment, as mentioned by other EU members. Methodology for Descriptor 9 is fairly harmonized and mostly based on Commission Regulation EC 1881/2006. However, in the Initial Assessment documents there are frequent data gaps and some improvements would be needed to provide an appropriate assessment. Some considerations from EU countries included the analysis of additional contaminants, sampling in a wider range of marine commercial species and development of new criteria regarding microbiological indicators. Regulatory thresholds are available for several substances, but further development is advisable if EU member's considerations are taken into account.

4. Conclusions/Discussion

From integration of information analysed on the structure of the considered international environmental frameworks, the EU 'Initial Assessment' reports, and the monitoring programs, it can be seen that positive efforts are made to harmonize methodological approaches between the MSFD and the RSCs in the SES, but there is still a lot of work to be done. This harmonization denotes making approaches compatible, comparable and coherent. For that reason, further collaboration, communication, information exchange and coordination is needed. Furthermore, harmonization is needed at technical level for: the selection of matrices for monitoring and assessment: selection of substances for monitoring and assessment, and the establishment of thresholds values for assessment and monitoring Strategies (e.g., periodicity, sampling grid planning, etc.).

These three international frameworks are at different stages in their own implementation timelines. Communication and coordination among them is essential for harmonization and comparability purposes. Particularly, UNEP/MAP and BSC are undergoing important updates in their methodological approaches to attain coherence with the implementation of the MSFD. All of these on-going implementation processes are on the way to improve synergy and coherence between MSFD and the Regional Seas Conventions for the protection of the marine environment in the South European Seas. Future works should take much attention on the monitoring programs so there can be coordinated efforts among EU and non-EU countries to protect from chemical pollution the SES not only at local/national levels, but also at regional level (e.g. deep sea and open waters).

5. Acknowledgements

We want to thank all the PERSEUS Team for the support given in the analysis of the EU 'Initial Assessment' reports.

6. References

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Use of in-vitro bioassays to characterize the environmental quality of sediments from the Adriatic and the Black Seas

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Abstract

The environmental quality of sediments from the Adriatic and Black Seas was assessed in-vitro by combining the use of the PLHC-1 cells, zebrafish-Pxr-transfected COS-7 cells and ovarian subcellular fractions from sea bass, which allowed to determine multiple endpoints: cytotoxicity, oxidative stress, presence of CYP1A inductors, endocrine disruptors (CYP19 inhibitors) and activators of Pxr. Sediments from harbours showed the highest anthropogenic impact, followed by those collected in the mouth of the Danube River. A gradient from the mouth of the rivers to the open sea was evidenced. This study highlights the usefulness of in-vitro bioassays as a screening tool to identify those sediments that could pose a risk to aquatic organisms and that require further action to improve their environmental quality.

Keywords: CYP1A, P450 aromatase, ROS, Pxr, PLHC-1

1. Introduction

The health of the marine ecosystem can be measured by the quality of the sediments since they are the main cycling compartment of aquatic pollutants. Sediments contain complex mixtures of organic compounds that could create stressful conditions for aquatic life, representing a risk to both ecosystem and human health. Thus, approaches to biomonitor sediment quality are essential in order to characterize the health status of aquatic environments and, ultimately minimize the threats and prevent the adverse effects to aquatic wildlife. However, surveying the effects and responses of aquatic organisms to sediment-bound pollutants remains a challenge, due to the complex geochemical nature of sediments and to the presence of multiple classes of pollutants. Besides, the toxicity and risk assessment of contaminated sediments cannot be solely based on chemical analysis as a strategy to characterize sediment quality, since chemical analysis does not provide information about potential hazards to the organisms (Chapman, 2007). Alternatively, in-vitro bioassays reflect an estimation of the biological activity of the pollutants present in the environmental sample, integrating the interaction between them and covering endpoints such as acute and long-term toxicity, bioaccumulation and endocrine effects, among others.

In this work, the environmental quality of marine sediments from the front of the Po and Danube river estuaries and selected near coastal cities (Ravenna and Constanta respectively) was assessed by combining the use of different bioassays based on the use of PLHC-1 cell line (cytotoxicity, CYP1A induction, oxidative stress), zebrafish Pxr-transfected COS-7 cells and ovarian microsomal fractions from sea bass (*Dicentrarchus labrax*), and multiple endpoints. This approach allows the detection of the cumulative impact of the unknown mixture of chemicals extracted from sediments and the identification of those sediments that contain significant amounts of cytotoxic compounds and/or CYP1A inducing agents, those that generate oxidative stress in fish cells or contain endocrine disruptors and/or PXR agonists. The use of multiple endpoints will allow the determination of specific modes of action of the complex mixtures of contaminants trapped in the sediments (Schnell et al., 2013).

2. Materials and methods

Surface sediment samples were collected along the Italian (Adriatic Sea) and Romanian coast line (Black Sea), around the mouth of the Po and Danube Rivers, close to main harbours, WWTP outflow, touristic resorts and city influenced areas (Fig.1).

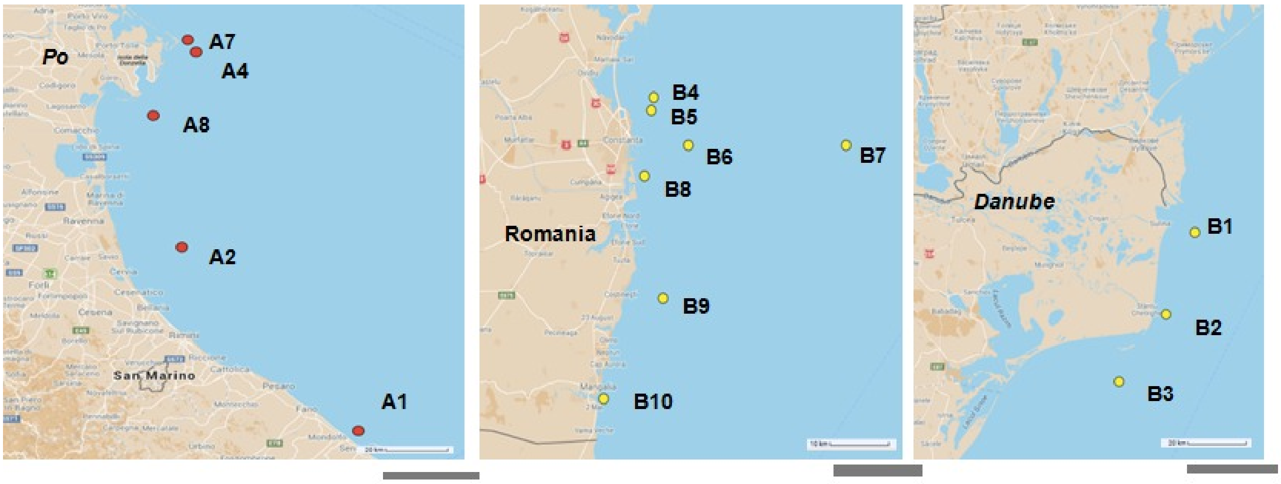

Fig.1 *Sample sites along the Italian (A1-A8) and Romanian (B1-B10) coast line.*

Chemicals from sediments were extracted with combinations of dichloromethane/hexane/acetone, evaporated and serially diluted in DMSO (Schnell et al., 2013). PLHC-1 cells were exposed for 24 h to sediment extracts at different concentrations (0.05 to 60 eQsed/mL) to measure different endpoints: (1) cytotoxicity, by using two fluorescent dyes: Alamar blue that measures metabolic activity, and CFDA-AM for membrane integrity, (2) oxidative stress (generation of Reactive Oxygen Species, ROS) by measuring the oxidation of 2',7'-dichlorofluorescein, and (3) CYP1A induction (EROD activity) by using 7-ethoxyresorufin as substrate (Schnell et al., 2013). The ligand activation of the zebrafish Pxr was assessed by the luciferase assay using Gal4-DBD/Pxr-LBD fusion in COS-7 monkey kidney cells exposed to sediments in order to detect agonists of PXR in the extracts (Lille-Langøy et al., 2015). Ovarian microsomal fractions of sea bass were used to detect the presence of putative endocrine disrupters in sediments that inhibit ovarian aromatase activity (Fernandes et al., 2014). Concentrations causing 50% effect were calculated by using Sigmaplot 11.0 software. Statistical differences were analyzed by one-way ANOVA with Dunnett test, using SPSS 19.0. $P<0.05$ was considered statistically significant.

3. Results

Along the Romanian coast, significant Pxr activation (Fig. 2A) and CYP1A induction was detected in sediments from Constanta harbour (B8; $EC50_{EROD,Pxr}$ 1.7 equivalent mg of dry sediment per mL -mg eQsed/mL-), which is affected by heavy boat traffic. Sediments from the Danube mouth contained also significant amounts of CYP1Ainducers and PXR agonists (B3& B2; $EC50_{EROD,Pxr}$ 6-8 mg eQsed/mL), and a gradient dependent of the water currents was found: sediments from the North (B1) had less anthropogenic impact than those from the South (B3), as dominant currents transport particulate matter and associated pollutants towards the South. Sediments from the Po River mouth (A7, A4 & A8) and Ravenna city (A2) contained significant amounts of CYP1A inducers ($EC50_{EROD}$ 15-20 mg eQsed/mL) and PXR agonists ($EC50_{Pxr}$ 15-17 mg eQsed/mL). Comparatively, these sediments had similar anthropogenic impact than stations B7 and B10 from the Black Sea, but less than stations B2, B3 and B8.

Sediments collected near the WWTP outfall of the city of Constanta (B5) significantly induced the generation of ROS in PLHC-1 cells (5-fold induction over non-exposed cells), followed by those collected in the Danube mouth (B3 & B2; 3-fold induction) and Constanta harbour (B8; 3-fold induction). Significant generation of ROS was also observed in A7, A2 and A1 (2.5-4-fold induction) from the Adriatic.

Regarding reprotoxicity, fish gonad bioassays revealed the presence of endocrine disrupting chemicals able to inhibit ovarian aromatase activity up to 50% (at 2 mg eQsed/mL) in sediments from Danube (B2), Constanta harbour (B8), and B9 (south of Constanta), while all the sediments collected along the Adriatic coast lead to an inhibition of ovarian aromatase below 20% (at 2 mg eQsed/mL) (Fig. 2B).

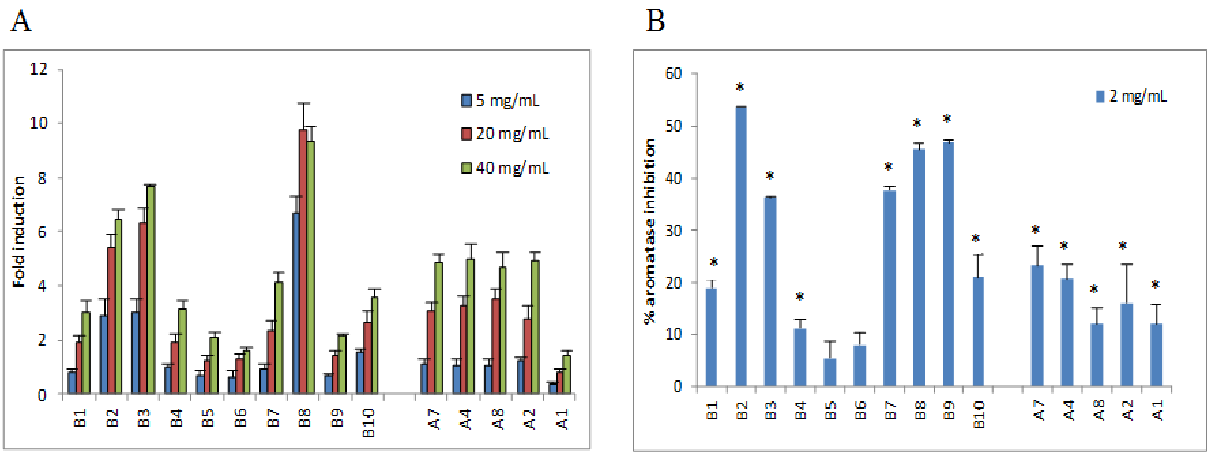

Fig. 2: *(A) zPxr activation in COS-7 monkey kidney cells and (B) inhibition of ovarian aromatase activity in sea bass by sediment extracts from the Romanian (B1-B10) and the Italian (A1-A8) coasts. *Statistically significant (P <0.05). Results expressed as mean ± SD (n=3) as fold induction over blank (non-exposed cells) or percentage of inhibition respect to controls.*

4. Conclusions/Discussion

The combination of different bioassays, focusing on cytotoxicity, CYP1A induction, detection of PXR agonists, ROS generation and inhibition of ovarian aromatase activity, provided useful information to assess the environmental quality of estuarine and coastal sediments and to discriminate between polluted and less impacted areas. The areas with the highest anthropogenic impact were mainly located in the Black Sea, corresponded to Constanta harbour (B8) and Danube mouth stations (B3 & B2). The less impacted zones were detected north of the city of Ancona (A1), north of the Danube mouth (B1) and at Cazino Mamaia (B4), an area exclusively dedicated to recreation and tourism activities. This study highlights a higher anthropogenic impact on sediments from the Black Sea (Danube and Constanta areas) when compared to those collected in the Adriatic (mouth of the Po River). Furthermore, this in-vitro approach may serve as a first screening tool to assess the quality of benthic ecosystems as well as the implementation and efficiency of environmental policies at a regional scale, allowing a significant reduction in the number of bioindicator organisms to be used in environmental monitoring studies.

5. Acknowledgements

Dr. Spagnoli Federico (Institute of Marine Science of National Research Council, Ancona, Italy) and Dr. Adra Oros (Marine Pollution Laboratory of National Institute for Marine Research and Development Grigore Antipa, Constanta, Romania) are greatly acknowledged for providing the sediment samples. Work financed by the projects "Policy-oriented marine Environmental Research in the Southern European Seas" (PERSEUS; agreement No. 287600) and "NILS Science and Sustainability" (ES07; ABEL-CM-01-2013).

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Linking the microbial community processes to the contamination by priority organic substances: in situ observations on coastal sediments of the Adriatic Sea (Italy)

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Abstract

In sediments microbial communities play an important role in driving the organic matter decomposition. The occurrence patterns of selected classes of organic priority substances together with changes in the functional parameters of the native bacterial communities were analyzed in coastal sediment of the Adriatic Sea (subtask 1.3.3 ADREX). Increasing concentration of polycyclic aromatic hydrocarbons was positively related to the microbial community respiration (R^2=0.69, $p<0.05$). This trend can potentially affect the C-fluxes in the trophic chain and let infer that greater attention in the MSFD should be paid to these parameters for a better definition of the good environmental status (GES).
Keywords: Polycyclic Aromatic Hydrocarbons, Nonylphenols, Bisphenol A, sediment, microbial processes

1. Introduction

Sediments are an important compartment of the aquatic environment acting as sink or source of organic matter, nutrients and pollutants. The western Adriatic margin receives large inputs of organic matter from both terrestrial and marine sources and potentially sequesters a significant fraction of organic carbon in its seabed. Sediments are not currently monitored for the definition of the environmental quality standard and no organic pollutants thresholds are given by EC for the quality definition. Conversely Environmental Quality Standards (EQS) are given by the Directive 2008/105/EC for surface waters, on the base of a list of 33 organic priority substances.

Benthic microbial communities are posed at the base of the heterotrophic chain and play an important role in driving the biological processes including the biodegradation. However in the current version of the MSFD (2008/56/EC) the microbial component is neglected.

Information on contamination of sediments by organic pollutants (e.g. Magi *et al.* 2002) and microbial activities in the Adriatic Sea (e.g. Danovaro *et al.* 2001) are available but scarce is still the information that combine the description of the organic pollution and its effect on the resident microbial communities.

To define the "good environmental status" (GES), the MSFD takes into account several descriptors including the "sea-floor integrity" (n. 6) and "contaminants" (n. 8), whereas the microbial benthic communities are still neglected.

In the frame of the PERSEUS Project (subtask 1.3.3 ADREX: Adriatic and Ionian Seas Experiment), two cruises were conducted in the Adriatic Sea (Italy) in order to verify the occurrence patterns of selected classes of organic priority substances (WFD, 2008/105/EC) in sediments together with the structural and functional parameters of the native bacterial communities. Then, three classes of organic pollutants of environmental concern were selected: 15 congeners of Polycyclic Aromatic

Hydrocarbons (PAHs), Nonylphenols (4-NP and two ethoxylates NPEO1, NPEO2), Bisphenol A (BPA).

2. Materials and methods

Sediment samples were collected in the Adriatic Sea, in coastal sites selected to represent a gradient of anthropogenic pressure. The samplings were performed on board of R/V Dallaporta (CNR) (November 2013) and R/V Explora (OGS) (October 2014) (Fig.1). Sediments, were collected by box corer and SW104 gravity-corer for a total of 80 samples of which 68 superficial and 12 cores. Polycyclic aromatic hydrocarbons (PAHs), Nonylphenols (4-NP, NPEO1, NPEO2) and Bisphenol A (BPA), were extracted by ASE with the appropriate solvent, followed by analytical determination with LC-MS and HPLC UV-fluorescence (Patrolecco *et al.*, 2010). The bacterial cell abundance was determined by epifluorescence microscopy (DAPI) and the rate of bacterial carbon production (BCP) was determined by measuring the ^{3}H-leucine uptake rate as described in Amalfitano *et al.* (2008). The community respiration rate (CR) was estimated by the measurement of the electron transport system activity (ETS, Zoppini *et al.* 2016). The bacterial growth efficiency was calculated as follows BGE=BCP/CR+BCP. All data were normalized according to the sediment dry weight.

3. Results

The highest mean concentrations of åPAHs (as sum of 15 congeners) were observed in the coastal area offshore the lagoon of Venice (831 ng åPAHs/g) (Fig.1). A decreasing trend in PAHs concentration was observed southward, up to reach the lowest mean concentration in the sites posed offshore Otranto (23 ng åPAHs/g). These pollution levels are considered in the literature as moderate (<1000 ng/g, Baumard *et al.*, 1998

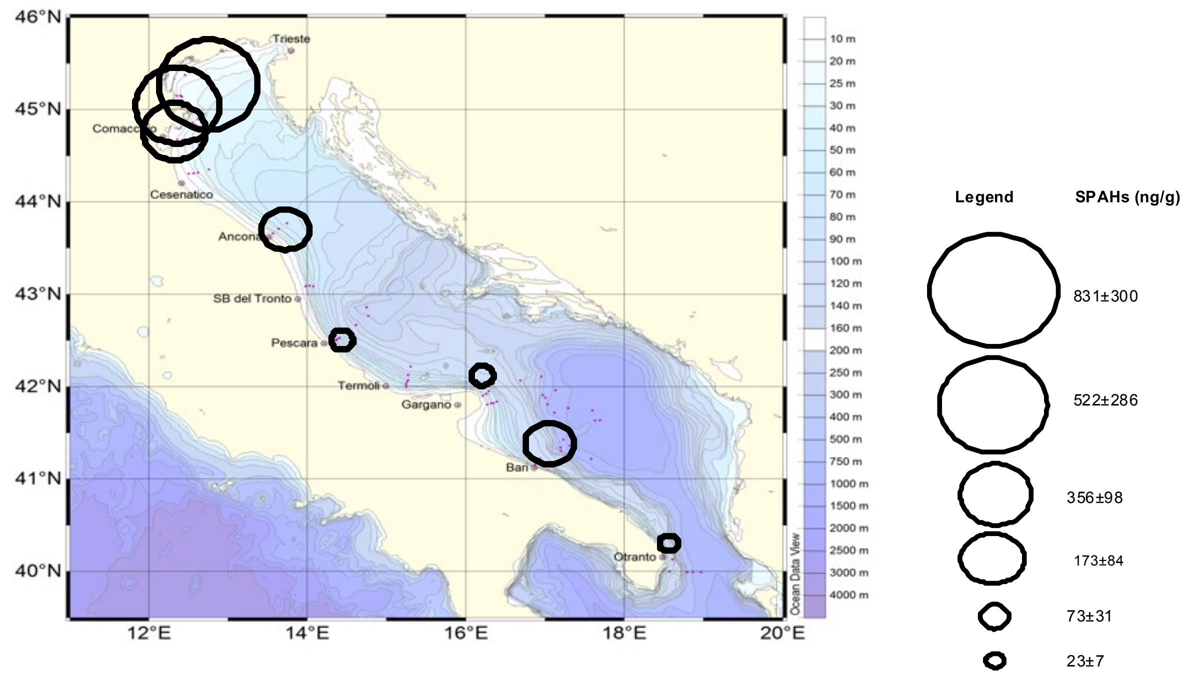

Fig. 1. *Mean concentrations of ΣPAHs in the surface sediments of the sampling areas*

The sum of the concentrations of 4-Nonilphenol (NP) and NP-ethoxylates (NPEO1, NPEO2) varied between 79-347 ng/g, whereas Bisphenol A (BPA) varied between 0.7 and 38 ng/g. The NP concentration was in the range of that observed in the Venice lagoon whereas BPA was in the lower range (Pojana *et al.* 2007).

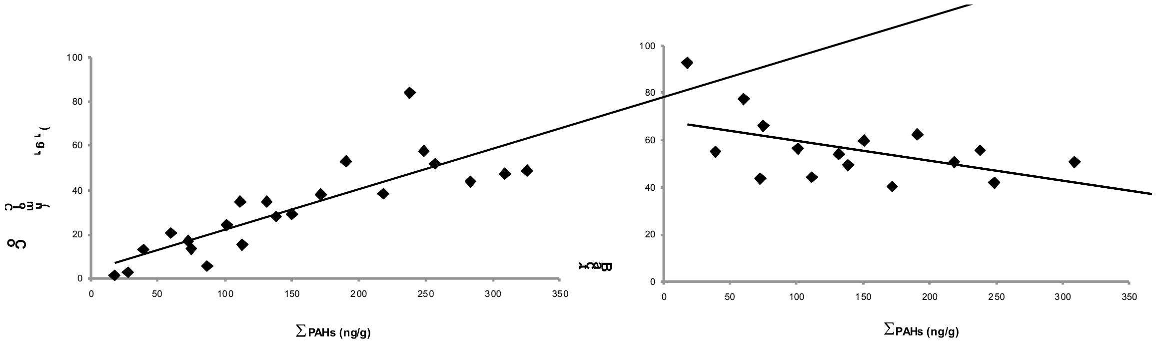

Fig. 2. *Regression analyses between PAHs concentration and functional properties of the microbial community*

Changes in the concentration of ΣPAHs in the surface sediments were positively related to changes in the microbial community respiration rates ($R^2=0.69$, $p<0.05$), when eliminating the most polluted sediments from the northern area, sited in front of Venice lagoon, Adige and Po river mouth (Fig. 2). Moreover the concentration of ΣPAHs was negatively related to BGE values ($R^2=0.26$, $p<0.05$) highlighting a reduction of the efficiency by which microbes use the substrate by increasing the contamination. Similar trend was observed between the concentration of the ΣNPs vs the community respiration rate and BGE ($p<0.05$). No significant trend was observed among changes in community respiration rates vs cell abundance and bacterial C production (BCP) ($p>0.05$).

We estimated the potential toxicity of sediment using the Toxic Equivalency Factors (TEFs) proposed by Nisbet and LaGoy (1992) for PAHs and NPs. In this way, the toxicity of a mixture can be expressed in terms of its Toxicity Equivalents (TEQs). The TEQs of each chemical are then summed in order to obtain a single PAH and NP TEQ value for the complex mixtures of organic compounds found in the sediment. We observed a positive and significant correlation between TEQ and the community respiration rates (ΣTEQ_{PAHs} vs CR $R^2=0.69$, $p<0.01$; ΣTEQ_{NPs} vs CR, $R^2=0.79$, $p<0.01$)) (Fig. 3).

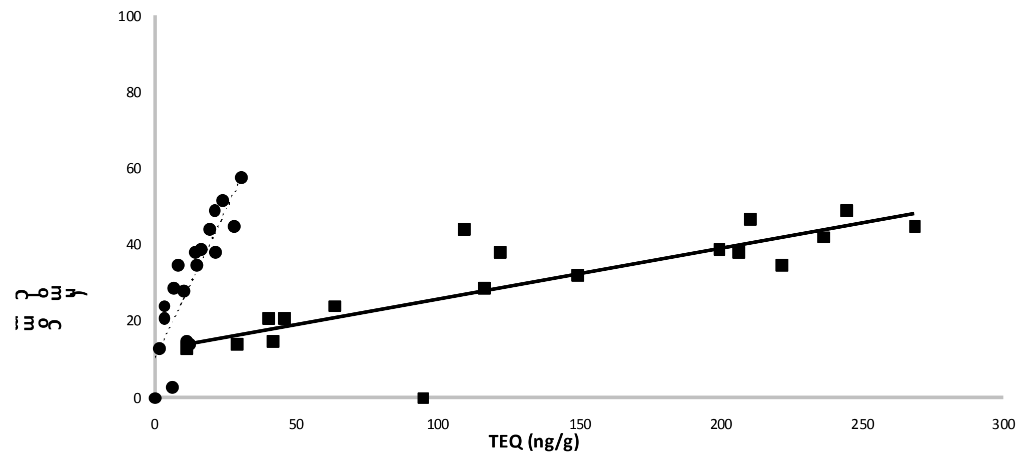

Fig. 3. *Regression analyses between potential toxicity of sediment evaluated by TEQ approach for PAHs (circles) and NPs (squares) and community respiration rates.*

4. Conclusions/Discussion

These preliminary results help us to shed light on aspects poorly studied on the effect of organic pollutants on the benthic microbial community. The adverse effect of the investigated pollutants on the microbial metabolism seems to undermine the metabolic equilibrium of this community posed at the basis of the food chain of marine ecosystems. At increasing pollutant concentrations the shift of the microbial metabolism toward the respiration rather than the production process, means a potential loss of energy (increasing CO_2 emission) for the food web. Moreover the increasing TEQ of PAHs and NPs seems to explain the increasing respiration rates of the resident microbial communities. In the context of the MSFD this result should draw greater attention to the importance of chemical and microbial characteristics for a better definition of the GES. By combining the information of chemical data with microbial community properties it is possible to meet the criteria defined in the MS in the frame of the descriptor *6: Sea-floor integrity* and descriptor *8: Contaminants*.

5. Acknowledgements

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Accumulation and trophic transfer of POPs in plankton and small pelagic fish in the Western Mediterranean and Adriatic Sea

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Abstract

The present study focuses on the transfer of POPs at the primary trophic levels in the Western Mediterranean and Adriatic Sea. The results show that levels of POPs in plankton are spatially variable and that marine plankton assimilates contaminants rapidly. The relationship between POP concentrations and size class of plankton and plankton $\delta^{15}N$ signatures are examined. The highest concentrations of POPs were found in bacteria /nano and picoplankton and small pelagic fish such as anchovy. The results indicate that prey-predator contaminant transfer is difficult to clearly distinguish within planktonic food-webs and anchovy is a pertinent vector for the transfer of contaminants to the open seas.

Keywords: bioaccumulation, biomagnification, persistent organic contaminants, primary marine food webs

1. Introduction

A global contamination of the oceanic and continental ecosystems by organohalogen persistent organic pollutants (POPs) is now well documented (Lohmann *et al.* 2007). Certain of these legacy compounds coming from various societal activities are now embedded in the natural biogeochemical cycles and are found in the marine environment which stands as an ultimate receptor for them (Durrieu de Madron *et al.* 2011; Johansson *et al.* 2006). A main concern with POPs is related to their strong propensity to bioaccumulate in marine organisms and to biomagnify along food webs (Fisk *et al.* 2001). The role of plankton, while recognized as playing a key role in the fate of POPs on a global scale (Dachs *et al.* 1999), is still a matter of scientific discussion as far as the mechanisms of POP uptake by plankton are concerned. There is no full agreement whether POP assimilation by plankton is dominated by partition equilibrium processes or by prey-predator relationships (Borga *et al.* 2004; Magnusson *et al.* 2007; Sobek *et al.* 2006). Whereas, the small pelagic fish represent an exploited resource in the Mediterranean and Black Sea and an essential trophic chain between plankton and the higher predators.

The present study is aimed at the better understanding of the bioaccumulation of POPs in the first links of the marine trophic chain including pico- and nanoplankton and in plankton-eating small pelagic fish (mainly anchovy) in the Gulf of Lion and in the Adriatic Sea. Biological tracers (stable isotopes signatures d15N, d13C, CHN composition, pigments and flux cytometry and communities compositions…) are used to better constraint "diet" sources and to determine biogeochemical conditions in which contaminants are taken up by plankton. The biogeochemical status of marine ecosystems (e.g. oligotrophic vs. mesotrophic) are also examined.

2. Materials and methods

The plankton and water samples were collected in the Gulf of Lion (GoL) and in the Adriatic Sea in spring and winter during several research cruises in 2011 and 2014 (Costeau 5 and 7 and Persmed 1 and 2). Plankton (phytoplankton and zooplankton) was collected with a net of 60 µm mesh size by repeated multiple horizontal 5 to 10 minutes tows carried out at the maximum of chlorophyll depth determined by CTD profiles. The content of each tow was fractionated on a sieve column to four size-classes (60-200, 200-500, 500-1000, 1000-2000 µm). The small pelagic fish (mainly anchovy) were caught in the narrow size range in the Gulf of Lions and in the Adriatic Sea during the reproduction season and the resting season of anchovy (cruises: PELMED-10 and -14; MEDITS -14). The different tissues and organs of the fish: muscle, liver, gonad, viscera and skeleton were sampled and pooled in sex and size classes. The physical and chemical parameters of the water column, as well as series of biological parameters: biomass and components of the planktonic communities, stable isotopes of carbon and nitrogen, pigments and CHN elemental composition were also determined to better describe the structure of the food web and infer potential contaminants transfer pathways. The plankton biomass was determined by vertical tows of bongo net allowing comparison of vertical and horizontal sampling tows. The content of the bongo net collector was also fractionated on the sieve column and each size class was recovered on pre-combusted and pre-weighed Whatman GF/F filter. PCBs and PBDEs were analyzed in dried biomass (at 50°C) according to the protocol described earlier (Munschy *et al.* 2004; Johansson *et al.* 2006). Briefly, the analyses of PCB were done by high resolution gas chromatography fitted with two electron capture detectors (ECD), using two columns of different polarities and PBDEs were analyzed by high resolution gas chromatography coupled to low resolution quadrupole mass spectrometer in ECNI[1] mode using methane as the reagent gas.

3. Results and discussion

POP levels, seasonal and spatial distributions in plankton

Mean summed concentrations of 26 PCB congeners determined in plankton were comprised between 30.1 ± 7.9 ng/g dw. and 16.5 ± 11.1 ng/g dw. and of all 12 PBDE congeners (excluding BDE 209) were 0.7 ± 0.24 ng/g dw. and 0.3 ± 0.25 ng/g dw. in February and April 2011 respectively in the Gulf of Lion. The median levels of PCBs are similar to what was determined in plankton samples in the open Mediterranean Sea and in a few Swedish lakes, whereas they are two times lower than median concentrations of PCBs in plankton in the Black Sea (Berglund *et al.* 2000; Berrojalbiz et al 2011) and 2 to 10 times higher than PCB concentrations reported of marine plankton in the Antarctic (Cabrerzio *et al.* 2013). The concentrations of CB 153 and BDE 47 in plankton were generally higher in the eastern part of the Gulf of Lion (except in the largest plankton fraction - 1000-2000 µm; Fig. 1), i.e. at the stations under direct influence of urban center of Marseille and of the Rhône River. This trend is not clearly distinguished in the winter period when the levels remain relatively high and show less variation between all stations including the most western part of the sampling area.

These results suggest that levels of PCBs in plankton in the GoL may be spatially influenced by the distance from contamination sources. These levels may be also related to seasonal variations, and environmental conditions, which likely influence the PCB uptake effectiveness and partition from water phase to plankton. At the stations near contaminant sources, marine plankton seem to be able to assimilate rapidly organohalogen compounds such as PCBs (Fisk *et al.* 2000; Dachs *et al.* 2002; Tiano *et al.* 2014).

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[1] *Electron Capture Negative Ionization*

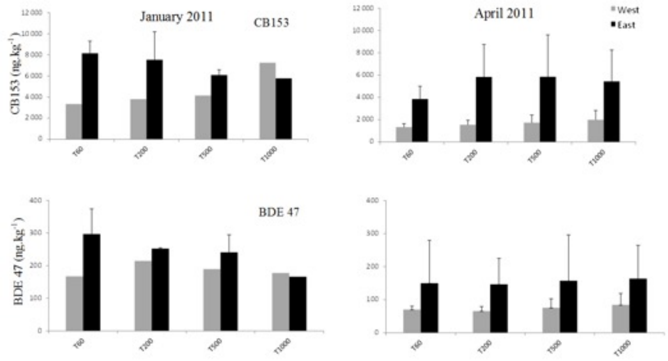

Fig. 1 *Mean CB 153 and BDE 47 concentrations (ng.kg^{-1} dw.) in plankton size fractions determined in January and April 2011 in the eastern and western part of the Gulf of Lion, Western Mediterranean Sea.*

POP concentrations versus plankton size classes, isotopic signature and taxonomy

The relationship between PCB, PBDE concentrations, size of plankton and d^{15}N signatures is compound, seasonal and space dependend. Generally the concentrations of PCB determined in the lowest 60-200 µm size class were not significantly lower than higher size classes (Fig. 1). However, CB 153 concentrations in plankton from the western part show a moderate but significant increase with plankton size and δ^{15}N signatures. Such relation is not observed in the eastern part of the GoL. It is not seen at any time and any place for BDE47. Furthermore, the highest mean concentrations of PCB and PBDE were now determined in the lowest fraction 0.7 - 63 µm of plankton (PERSMED-1; November 2013). This fraction shows significantly different δ^{13}C and δ^{15}N signatures from other plankton fractions, indicating high contribution of bacteria /nano and picoplankton to organic carbon pool in these samples.

The PCB concentrations in the lowest size class dominated by phytoplankton are related to the passive diffusive partition uptake of contaminants (Sobek *et al.* 2006). Significant, linear regression was found between bioaccumulation factor of CBs congeners and their K_{ow} partition coefficients in both phytoplankton and zooplankton allied size classes (Fig. 2A). Whereas, no dilution effect was observed between PCB concentrations and plankton biomass (Fig. 2B). These results diverge from the "biomass dilution effect" process, which implies the decrease of PCB concentration in plankton with increasing planktonic biomass (Berrojalbiz *et al.* 2011; Frouin *et al.*, 2013). The constant biomagnification factor (BMF_{zoo_phyto}) over the whole range of PCB K_{ow} indicates also that biomagnification could not be evidenced with this set of results (Fig. 2C).

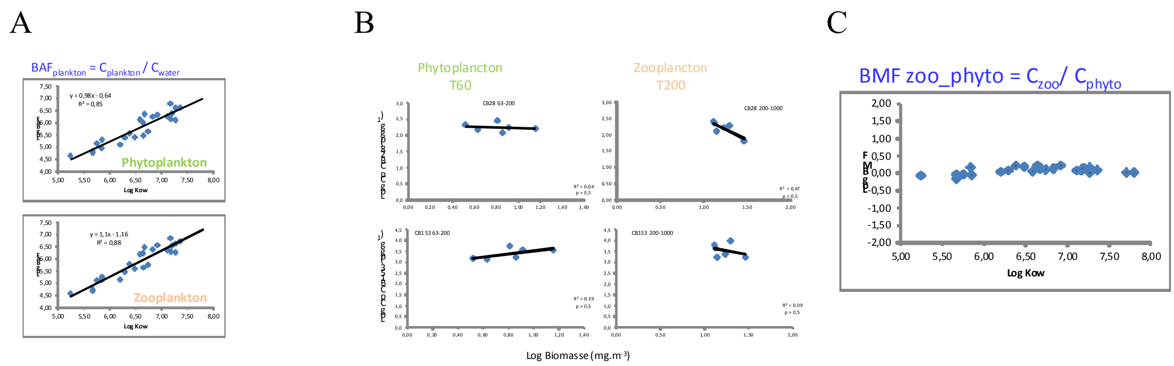

Fig. 2. *Log-log linear regressions between Bioaccumualtion factors (BAF) and octanol-water partition coefficients (K_{ow}) of all studied PCB congeners in both phytoplankton and zooplankton allied size classes (A); Log-log linear regressions between plankton biomass in the water column and concentrations of selected PCB congeners in phytoplankton and zooplankton size classes (B); Relation between log of biomagnification factors log(BMF_{zoo_phyto}) over whole range of log(K_{ow}) for all PCB congeners (C).*

4. Conclusions

Our approach in this study embraces the ecological and biogeochemical dimensions of the food web and its contaminants. It is based on the simultaneous use of chemical "tracers" (organic contaminants) and biological "tracers" (stable isotopes of carbon and nitrogen, pigments, CHN elemental composition…). The parallel study of the dynamics of these tracers provide quantitative and qualitative data on the mechanisms of the bioaccumulation of toxic substances in plankton and in the tissues of small pelagic fish as well as the influence of ontogenic factors (growth, reproduction, migration – not discussed in the short communication).

This study indicates that prey-predator contaminant transfer is difficult to clearly distinguish within planktonic food-webs especially in the field studies. The higher zooplankton size classes are composed of organisms with different diets, including herbivores, carnivores and detritivores, prone in addition to adapt their diet to the quantity of available resources. Consequently, the biomagnification of PCBs over the range of plankton size classes was frequently not observed in the field studies. Furthermore, size class and isotope signatures of plankton do not necessarily reflect trophic relationship and complex ecology in plankton communities. The full data and results of this study, including those from the Adriatic Sea as well as questions of trophic transfer of contaminants to the small pelagic fish will be further discussed.

5. Acknowledgements

This study is part of COSTAS and PERSEUS projects (ANR-CES-007; EU-FP7 Grant N° 287600). We wish to thank all crew members for their support during science cruises on R/V Europe and R/V Antea (GenAvir and IRD).

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Session 3

Lagrangian Observing Systems in the Southern European Seas: REVIEW, GAPS AND UPGRADE

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Abstract

The existing Lagrangian observing systems in the Southern European Seas (SES) were analyzed, gaps were identified and recommendations were given on how to fill them in order to serve the scientific and socio-economical needs of PERSEUS and the more general scientific and strategic society needs of the SES over the longer term. Lagrangian instruments include surface drifters and profiling Argo floats which measure physical and biogeochemical/optical properties near the sea surface and in the water column, respectively. The improved SES Argo float network upgraded as part of PERSEUS is described after a brief summary of the review the existing systems.

Keywords: Surface drifters, Argo floats.

1. Introduction

The overall objective of workpackage 3 (WP3) of the PERSEUS project was to upgrade and expand the present observing capacity in the SES towards fulfilment of the scientific and society needs addressed by the project with an emphasis on the characterization of the present state, increasing forecasting capabilities and the provision of solid grounds for the implementation of European Marine Strategy Framework Directive (MSFD).

To this end, the first objective of WP3 was the identification of needs (from local to basin scale), of existing observing capacities and of gaps to be filled. In particular, a review of the existing in-situ observing capacities that enable monitoring the SES at local and basin scales with Lagrangian profilers and surface drifters was carried out (Poulain et al., 2012). It is summarised in the next section. Following this review and the identification of gaps, specific SES observing systems were upgraded as part of PERSEUS (see Poulain et al., 2015 and other PERSEUS reports). Here below we describe the upgrade of the Argo float network in the SES in terms of geographical expansion and the addition of key biogeochemical parameters.

2. Review of existing Lagrangian observing systems in the SES

The SES have been sampled by Lagrangian instruments more or less uniformly over the last decades, providing data on surface temperature and currents (drifters) and temperature and salinity profiles, subsurface currents (floats) in most areas of these seas (see early review papers by Poulain et al., 2007 and Poulain et al., 2013). More recently, floats have been fitted with new sensors to measure biogeochemical properties (dissolved oxygen, chlorophyll concentration, etc.) and with interactive satellite telemetry (Iridium and Argos 3) allowing the collection of multi-parametric data with optimized/adaptive sampling.

The number of Argo floats active in the SES in December 2012 was about 50 (Figure 1), including a few French floats equipped with biochemical/optical sensors in the northwestern Mediterranean Sea. Although this number is commensurate with the international Argo standards, a higher density of floats is needed given the smaller scales of variability of the SES with respect to the . The following specific gaps were identified: 1) In terms of coverage, the Aegean, Algerian Current, the southern and eastern Ionian and the southern Levantine Basin were less/scarcely sampled. There was a strong need to seek ships of opportunity and collaboration with North African countries in order to deploy and or recover floats in these areas. 2) Regarding the multi-parametric observations, floats with oxygen and biochemical/optical sensors were missing in the Black Sea. As a result, it was highly recommended to increase the number of floats active in the SES and to equip more floats with oxygen sensors, and some of them with biochemical/optical sensors in the near future. In general, it was recommended to deploy at least 30 Argo floats in the SES on a annual basis.

Fig. 1. *Argo floats active in the SES in December 2012.*

In total, for the time period 1986 – 2012, more than 1450 surface drifters have beed deployed in the SES as part of national and international research and operational projects (Figure 2). Most of the drifters were of the CODE and SVP designs. However, the temporal distribution of the drifter data is very intermittent due to the relative short lifetime of the drifters. The drifter population in the SES reached its maximum in May 2003 with more than 70 active instruments. At the end of 2012, only 9 drifters were active. Major gaps were found in the Aegean, Levantine and Black seas. It was recommended to deploy a minimum of 50 drifters annually throughout the SES.

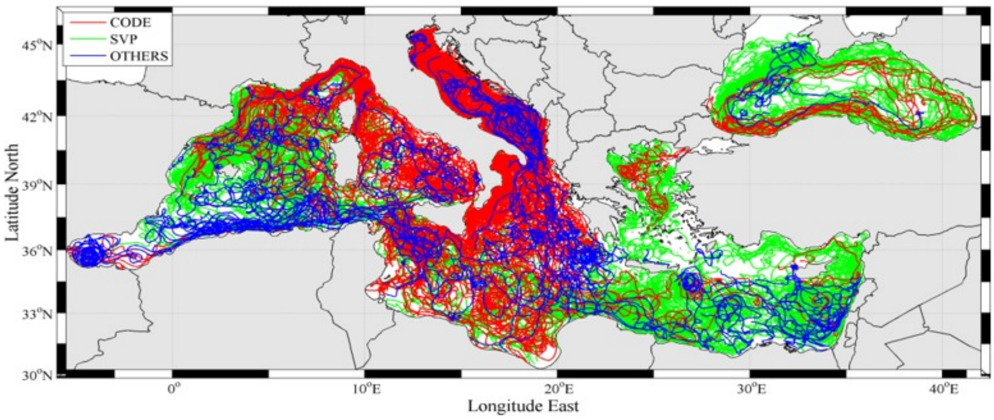

Fig. 2*. Composite diagram with all the tracks of surface drifters operated in the SES in 1986-2012, color-coded as a function of drifter types.*

3. Upgrade of the Argo Network in the SES

The Argo fleet in the SES has been expanded and upgraded with the deployment of a total of 27 PERSEUS floats since the beginning of the project in 2012, some of them directly or partially funded by PERSEUS, other considered as in-kind contributions from other projects. The trajectories and last positions of all the PERSEUS-related floats are shown in Figure 3. As of 24 July 2015, 11 floats were active (green dots). Thanks to PERSEUS, the Argo fleet in the SES has been upgraded in terms of numbers of floats deployed and of expanded geographical coverage, but also in terms of additional parameters been measured such as nitrate and hydrogen sulfide. For instance, an Italian bio-float equipped with, among other sensors, a modified SUNA instrument to measure simultaneously nitrate and hydrogen sulfide concentrations was deployed in the western Black Sea in spring 2015, in collaboration Bulgarian colleagues. An example of the first profiles of nitrate and hydrogen sulfide concentrations measured by an Argo float in the Black Sea is depicted in Figure 4.

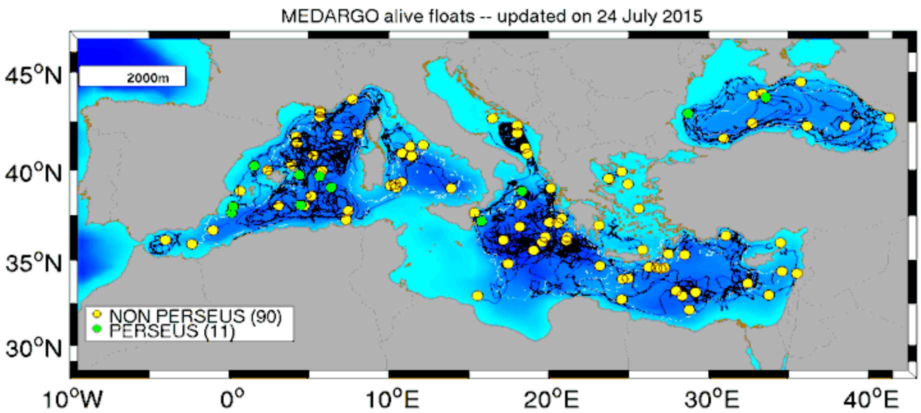

***Fig. 3**. Trajectories and last profile positions (colored dots) of all the active PERSEUS (green dots) and non PERSEUS (yellow dots) floats in the SES in late July 2015.*

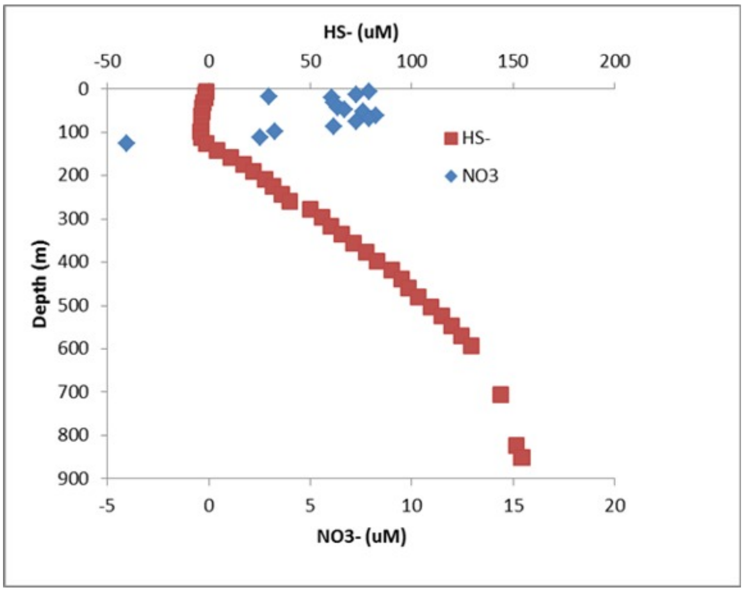

***Fig. 4**. Example of profiles of nitrate and hydrogen sulfide measured by the Italian Provor-NUT float (WMO 6901866) in the western Black Sea.*

4. Conclusions/Discussion

After a review of the existing observing systems in the SES, several specific systems were improved and upgraded as part of the PERSEUS project. In particular, additional Argo floats we deployed in some basins of the SES, some of them including state-of-the-art novel biogeochemical sensors. In late July 2015, there were 11 active PERSEUS floats, out of 101 active floats in the SES, that is about 10% of the entire SES float network. Hence, PERSEUS had a significant impact to improve the Argo network in the SES.

5. Acknowledgements

We would like to thank all the people who contributed to the PERSEUS WP3 review of existing SES observing systems, and those who deployed Argo profiling floats over the last few years in order to upgrade and expand the SES Argo network (CSIC-IMEDEA and SOCIB in Spain, CNRS/UPMC in France, OGS in Italy, HCMR in Greece, in OC-UCY in Cyprus, IO-BAS in Bulgaria and GeoECoMar in Romania).

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Glider monitoring under PERSEUS as a contribution to ocean observing in the SES with implications for future integrated observing system development

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Abstract

The use of gliders as a key new tool for oceanographic observations is growing. In this review, the results of recent glider activity under PERSEUS are highlighted; these clearly show the unique temporal and spatial scales that gliders can access and how effective they have been in observing the complex oceanography of the Mediterranean, particularly related to ocean variability. Gaps in our coverage remain and so suggestions on how to develop, from this base, a glider component for an integrated observing system for the Mediterranean and Black Seas are proposed.
Keywords: gliders, ocean observing systems, Mediterranean and Black Seas.

1. Introduction

In recent years, gliders have emerged as an important new tool for ocean observing, including long term observations of key ocean transects, coastal to open ocean interactions, deep water formation, fine scale vertical velocity structures, mesoscale to sub-mesoscale features, physical to biochemical coupling, and marine predator interaction. Operationally gliders now provide critical information for ocean forecasts, through data assimilation, and can provide observations from within hurricane pathways. Finally a collaborative glider network provided critical sub-surface information during the Deepwater Horizon oil spill crisis. A recent review of glider research can be found in Rudnick et al. (2015).

Part of the success of gliders is that they respond directly to current challenges in ocean observations, and there is an emerging consensus that gliders can uniquely access critical time and length scales (Rudnick et al. 2015). Gliders fill an important gap, they routinely sample at a spatial resolution of order 100's m (on shelf) to 2 – 6 km (open ocean), extending our view from the global surface measurements of satellite SST/ocean colour to depths of 1000 m and providing details on mesoscale to sub-mesoscale and coastal features not captured by satellite altimetry. Through their autonomous nature, all weather navigation and lower operational cost (as compared to traditional ship missions), they enable access to monitoring at temporal and spatial scales not previously economic, in 2D, and covering extended areas from coastal to open ocean regions. Gliders complement existing platforms, while opening up new capabilities for multidisciplinary, autonomous and high-resolution observation. PERSEUS aimed to contribute to the development of a glider network in the Southern European Seas (SES), as a part of the broader aim of responding to scientific and societal needs through new multi-platform observing systems, with emphasis on the characterisation of ocean state and ocean variability, and with provision of monitoring systems to meet the needs of MSFD.

2. PERSEUS glider mission results (to June 2015)

Under PERSEUS, pre-existing glider endurance lines were supported and new 'proto' endurance lines' were undertaken, as well as a synoptic, intensive multi-platform experiment. In total during PERSEUS (to June 2015) gliders were operational for over 2,300 days, completing 5,700 km on mission and obtaining over 42,000 profiles of the water column (see table 1).

Table 1. *Summary of glider activity by operator, project and transect monitored between Jan 2012 and Jun 2015*

Operator	Project	Transect	Missions	Days	Km	Profiles
Western Mediterranean						
CNRS	MOOSE	Moose T00	13	465	19,329	8,685
CNRS	MOOSE	Moose T02	13	610	12,676	7,140
SOCIB	SOCIB 'canales'	Ibiza Channel 'canales'	23	521	11,021	18,994
SOCIB (JERICO TNA)	GABS	Menorca-Sardinia	2	91	1,689	1,127
CRNS (JERICO TNA)	MUSICS	Sardinia Channel	1	38	990	918
SOCIB (JERICO TNA)	ABACUS	Mallorca-Algeria	4	74	1,574	866
SOCIB (IMEDEA-CSIC/UIB & JERICO TNA)	ALBOREX	Alborex Experiment	2	12	243	528
Eastern Mediterranean						
OC-UCY	Cyprus National Glider Monitoring Program	Eastern Levantine 'butterfly'	3	523	9,179	3,366
OGS	CONVEX	Southern Adriatic Pit	3	28	572	491
Total			64	2,362	57,273	42,115

Such statistics give an indication of the step change in temporal and spatial monitoring resolution that gliders can bring. However, it is the scientific results of these missions, as highlighted here, that will indicate the success of these glider initiatives. We have summarised below the key new findings from the PERSEUS glider activities in the Western and Eastern Mediterranean. Note: these summaries cover the time period Jan 2012 - June 2015 and the gliders sampled as standard the following key variables: temperature, salinity, dissolved oxygen, turbidity and Chl-a fluorescence.

Western Mediterranean:

MOOSE 'endurance line' monitoring: 26 glider missions, covering 2 transects and ranging from a few days to 3 months duration, were completed by CNRS as part of the MOOSE monitoring program. From these missions insight into the connection between seasonal variability of the Northern Current and regional ocean heat storage was gained (Houpert et al. 2014), the processes and phases of DWF, at fine scales, were identified and the associated changes in water column heat and salt content understood (Houpert et al. 2015), and the modelling of these key events improved (Estornel et al. 2015). In addition, coherent sub mesoscale (5 km radius) eddies were characterised and their impact on circulation identified (Bosse et al. 2015) and the interaction between cascading shelf water and open sea DWF investigated (Durrieu de Madron et al. 2013).

Ibiza Channel 'endurance line' monitoring: 23 quasi-continuous 'canales' glider missions, generally of order 26 days duration, were completed by SOCIB as part of the regional long term, multi platform ocean monitoring program (Tintoré et al. 2013). The fast repeat sampling of the Ibiza Channel enabled high frequency variability in this N/S exchange to be identified (Heslop et al. 2012), and, in combination with historical ships records annual mean patterns in the exchange to be defined. Vigorous, episodic surface inflow events were identified, which can have a significant impact on the regional ecosystem in a biodiversity hotspot. This insight is now used to validate and improve regional model representation.

GABS project: A Menorca-Sardinia 'proto-endurance line', operated by SOCIB for CNR-IAMC under the JERICO TNA program. In 2 missions, of over 40 days duration, the transect was sampled 4 times. This showed that the onset of a bloom occurred soon after a decrease in wind-driven mixing, timing that is supported by satellite imagery, and subsequent frontal-related re-stratification played a key role (Olita et al. 2014).

MUSICS project: A Sardinia Channel 'proto-endurance line', operated by CNRS for SAROST, under the JERICO TNA program. In a chronically under sampled area, one mission of 38 days duration sampled this transect 6 times. The high spatial and temporal resolution of the glider observations are unique for this region, lenses of fresh water were observed related to the meandering of the Algerian Current and the generation of an eddy, with associated upwelling that caused high concentrations of chlorophyll. The transect location was close to a SARAL track to enable inter-comparison with satellite altimetry and regional models.

ABACUS project: A Mallorca-Algeria 'proto-endurance line', operated by SOCIB for the University of Napoli Parthenope, under the JERICO TNA program. Two missions of over 30 days duration sampled this transect 4 times, during one transect a 'butterfly' loop was interactively inserted into the mission to sample an eddy, identified from altimetry and SOCIB drifters. A unique 3D view of this anticyclonic eddy was gained, with the thermohaline properties indicating that a perturbation of the Algerian Current was the source, a hypothesis supported by satellite data (Cotroneo et al. 2015). Oxygen and chlorophyll concentrations indicated that production levels varied between Algerian Current and Mediterranean waters masses. Comparison with satellite altimetry (glider track close to SARAL track) will be used to assess circulation variability.

ALBOREX Experiment: A multi-platform intensive and synoptic experiment was completed in the Eastern Alboran Sea, along an intense front where Atlantic and Mediterranean waters meet and intense mesoscale and submesoscale features are generated. Lead by CSIC, the experiment included different oceanographic platforms sampling concurrently, including 2 gliders operated SOCIB, in order to capture the intense but transient vertical motions associated with these features. The glider observations revealed submesoscale structures associated with the frontal zone; a deep chlorophyll maximum (DCM) and subducted 'tongues' of temperature, chlorophyll and oxygen. The data resolution enabled the relationship between mesoscale and submesoscale dynamics to be studied and compared with a process study model that resolves vertical transport.

Eastern Mediterranean:

South Adriatic Pit: In 2014 one mission of 3 weeks duration was undertaken along a new glider endurance line, operated by OGS. The results are preliminary however it is anticipated that regular winter missions will provide high-resolution detail of DWF events, interannual variability and the impact on circulation.

Cyprus National Glider Monitoring Program: Three 'butterfly' missions, of 5 to 6 month duration, were completed by OC-UCY. The glider monitoring has enabled seasonal and interannual variability of the Cyprus warm core eddy, in location, extent, structure and intensity, to be characterised.

3. Insight gained from PERSEUS glider missions

The glider missions within PERSEUS have delivered new insight into critical temporal and spatial scales, uniquely accessible by gliders, and enabled the extension into historically under sampled regions. Visibility is provided of sub seasonal to interannual variability particularly, but not exclusively, for circulation, transport and exchange. Also important is the characterisation of sub-mesoscale to mesoscale features, and associated physical to biological interactions, observations of DWF, and shelf to open ocean interactions. Glider missions also appear to have an important emerging role in verifying ocean models and are frequently used to augment satellite datasets. With this clear capacity to advance our understanding, it might be suggested that a specific glider component in a Mediterranean and Black Sea Ocean Observing System would enhance observing capability.

However there are still many gaps in the current coverage (see figure 1). Given gliders many advantages why is this and can we learn something from the PERSEUS experience?

Fig. 1: *Map of PERSEUS related glider activity in the SES from Jan 2012 to Jun 2015*

Rudnick et al. (2015) observe that despite several calls for coordinated national or international glider observing networks that such systems do not yet exist, although the PERSEUS initiative could be considered a proto-network for the SES. They suggest that this is because of an over-hype of gliders as a platform. We believe, in line with Rudnick et al. (2015) that one of the causes of this hype vs. delivery gap is that gliders are complex machines, routinely operated. It takes at least 2 years to become a skilled glider pilot and a team is required to run 24/7 operations on a routine basis. This makes gliders an investment for the long term; some countries have invested in centralised national facilities, however in the Mediterranean regional hubs have also naturally developed around groups that have made this investment (see table and map). The second aspect that we believe slows the spread of glider use is the processing of glider data. This is not (yet) 'plug and play', requiring time to understand the specifics of glider sampling ('V' flight path, relatively slow speed and sensor precision), and to data manage, quality control and analyse such large datasets. However, with the right focus, these issues can be solved.

4. The glider component in an integrated SES observing system

The development of a glider observing component in a Mediterranean and Black Sea observing system can be based on current glider groups with perhaps 3 additional glider facilities strategically located to in key regions, satellite facilities and/or TNA access of these main facilities could then extend coverage to the whole SES area. These main facilities would be responsible for collecting high quality datasets, e.g. with in situ/cross calibration corrections to agreed standards, and for providing this data to EU ocean data portals. The sharing of processing knowledge within the community should be encouraged, for example through glider data workshops to help develop standards (e.g. as in JERICO, GROOM, EGO) and to facilitate the use of new tools e.g. SOCIB Glider Toolbox. This would also support the calibrating and testing of new glider sensors. The capacity of gliders to bring greater resolution to shelf/coastal observations, in support of MFSD, has yet to utilised in the Mediterranean. Thus specific projects should be funded to develop capability in these areas for future basin wide application. In addition, further biogeochemical observations should be undertaken on existing transects as standard, with associated quality control and calibration, to quickly expand our knowledge of ocean state and variability in this area. Finally, it is worth considering the capacity of gliders to respond to emergencies, such as oil spills, for example through the funding and testing of appropriate sensors and response mechanisms.

4. Acknowledgements

CNRS, SOCIB, OGS and OC-UCY glider teams; EU FP7 Projects PERSEUS and JERICO.

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Hydrodynamical properties of a cyclonic eddy in the channel of sardinia monitored by Glider and Satellites Observations

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Abstract

In summer 2014, 6 repeated sections were carried out in the Channel of Sardinia (PERSEUS' Subtask 3.3.1) using adeep water glider (up to 1000m), which was granted thanks to the support of JERICO TNA (EU-FP7). Here, we are focusing especially on a joint analysis of in-situ and satellite data (SST, Sea Color) to understand the behavior of a cyclonic eddy observed in the area. In particular, we highlight the vertical motion inside the eddy, which "pumps" relatively cold and salty water to the surface and induces an enrichment of these surface water in Organic Matter and Chlorophyll.

Keywords: Vertical motion, Tunisia

1. Introduction

The Sardinia Channel is a zonally oriented passage connecting the Algerian and the Tyrrhenian basins, with a sill depth of about 1900 m. In spite of the amount of campaigns achieved and results obtained about the circulation in this area, from the precursor work of Garzoli and C. Maillard [1979] to that of Astraldi [1999], the Sardinia Channel is still one of the regions where the dynamical processes and water exchanges are not clearly identified, especially at mesoscale and sub-mesoscale level. On top of that, no significant campaign have been carried out since 15 years. The main knowledge about the water masses crossing this region mostly concerns the AW (Atlantic Water) and the LIW (Levantine Intermediate Water). Along the Algerian coast, the AW is transported mainly by the Algerian current [Millot,1985]. The unstable character of the Algerian Current leads to meanders a few tens of kilometers in wavelength, which may develop into eddies downstream of 1–2E. These eddies have a clear surface signature that can be tracked by satellite remote sensing (infrared, visible, and altimetry). Both cyclonic and anticyclonic eddies are generated and propagate downstream eastward at approximately 3–5 cm/s [Millot, 1985; Font et al., 1998]. Only anticylonic structures seem to grow and become large and energetic. When this occurs (few times per year), these structures are usually called Algerian Eddies (AEs, [Puillat et al., 2002], [Taupier-Letage et al., 2003]). The AEs along slope-downstream propagation usually ends in the Sardinia Channel, where AEs interact with the bathymetry and can remain almost blocked in the Channel area for several months before collapsing [Puillat et al., 2002].

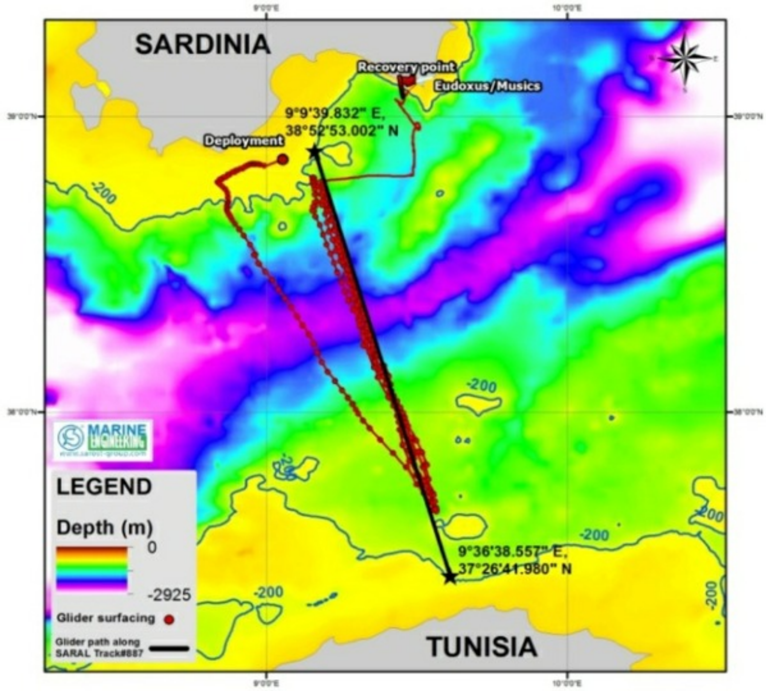

***Fig**.1: Glider tracks across the Sardinia Channel (Red dot are Glider surfacing locations).*

Conversely here, we focus on the evolution of a mesoscale cyclonic eddy using jointly glider data and satellite observations, and in particular, the role of this eddy in vertical transfer of phytoplankton and organic matter. We must mention that gliders can resolve up to sub-mesoscale along their trajectories, but are limited in terms of coverage and/or ability to compensate strong current [e.g., Ruiz et al., 2009]. In contrast, satellite remote sensing can provide mesoscale-resolving measurements of sea surface level, and up to submesoscale views of the temperature and ocean color fields.

2. Materials and methods

The gilder carried out 3 return trip of about 2x129 km between South Sardinia and Northern Tunisia (1st:16 Aug. - 27 Aug. 2014, 2nd: 27 Aug. - 7 Sept. 2014, 3rd:7 Sept. -19 Sept. 2014).A total of 750 vertical profiles were collected during the period. However, as we can observe in Fig.1, the 1st leg was relatively far from the expected route because, just after its deployment, the glider has drifted to the west. Starting from the 2nd leg, the glider has closely followed the track #887 of the Satellite SARAL(black solid line) as requested.

The innovation stands in the high spatial resolution, in the temporal repetitivity and in the number of parameters sampled simultaneously by the Glider (CTD, O2, various optical sensors). We remind that one of the aims of the whole experiment is to analyze the hydrological properties of the surface and intermediate water masses, their variability, mixing and dynamical processes. But, as mentioned above, this paper is focusing on an eddy, characterized by a colder (23°C) but saltier water (38.3psu), observed in the central part of the channel (Fig-2).

Fig-2 and Fig-3 (Hereafter) show respectively the vertical sections of Temperature (Left), Salinity (Right), Chlorophyll (bottom, Left) and Colored Dissolved Organic Matter (bottom, Right) from the surface down to 100m depth and for the period spanning from 03-09-2014 to 07-09-2014(Leg#4).

Near the surface, lenses of fresher water are observed at about 20m depth, all along the section, and they correspond to meandering of AW, which are advected from West to East by the Algerian current. In contrast, a local maximum of Salinity (>38.3 psu) is observed at ~40m depth and at the vicinity of 38.25°N.On the other hand, the optical sensors (phytoplankton and CDOM) reveal maximum concentrations at ~70m depth. On the other hand, the horizontal distribution of SST (Fig-4) is obtained from infra-red measurements collected by satellite radiometers and statistical interpolation (MyOcean SST nominal operational product for the Med Sea).The corresponding sea surface salinity maps are obtained from MyOcean numerical model. These data are interpreted in relation with the Glider data acquired during the same period in the same area (38°.1N, 9.4°E).

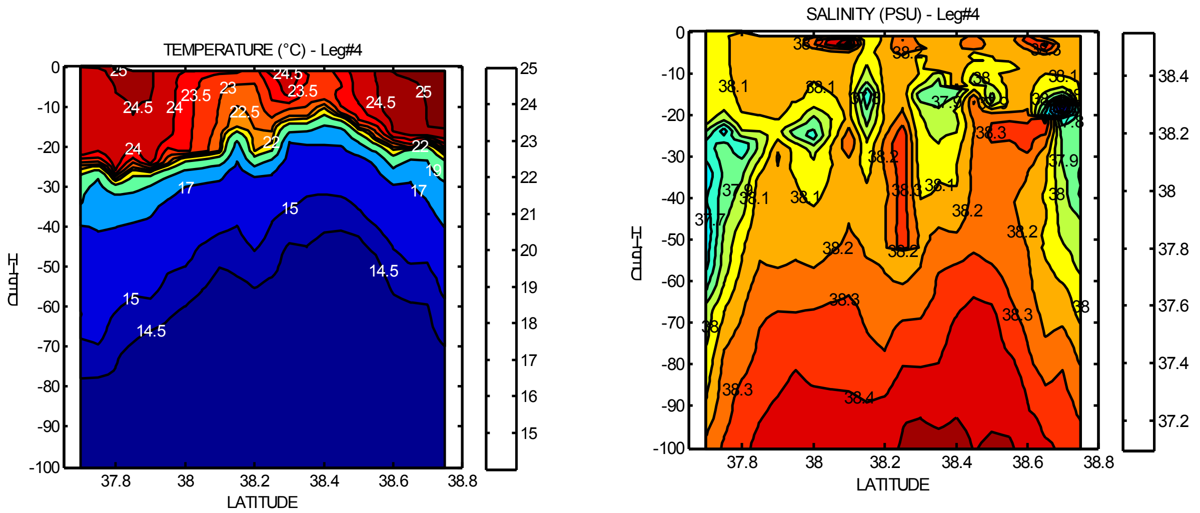

Fig. 2: *Vertical section of in-situ Temperature (Left) and Salinity (Right) in the 100m surface layer obtained by Glider during the fourth leg (03-09-2014 to 07-09-2014).*

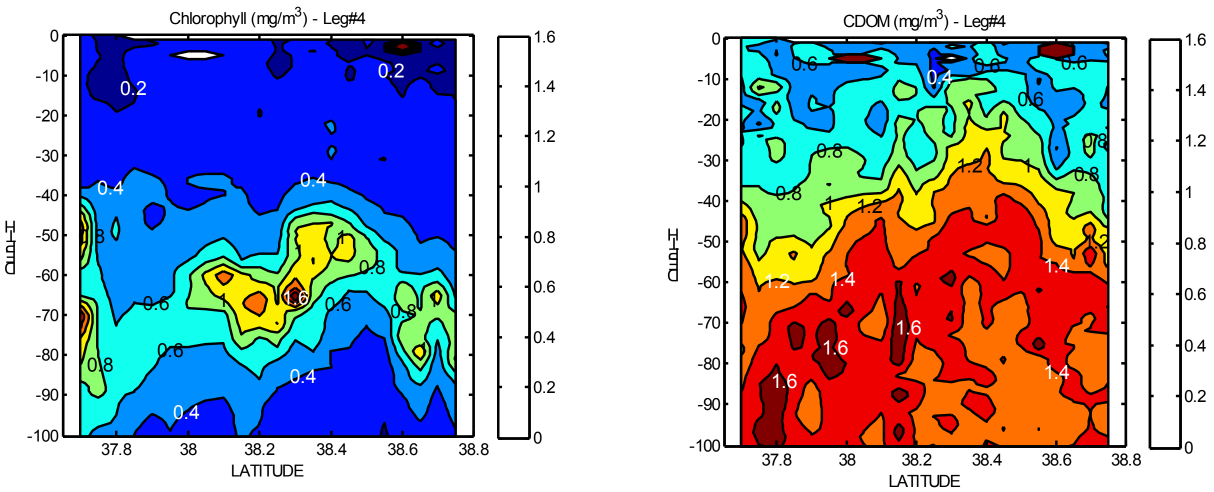

Fig. 3: *Vertical section of in-situ Temperature (Left) and Salinity (Right) in the 100m surface layer obtained by Glider during the fourth leg (03-09-2014 to 07-09-2014).*

3. Results

One particularly interesting event occurred during the glider monitoring and was observed around the first week of September 2015. The SST maps (Fig-4, hereafter) clearly shows the signature of an eddy that was generated and advected by the meandering of the AC.A water vein, coming from the North-West along the Southwestern continental slope of Sardinia, feeds the eddy, which shows a time-varying radius of 20 to 36 km. Progressively, two main cells of relatively colder water (23.4°C) are created and observed at the sea surface. The shape of the SST anomaly (and the SST distribution on the preceding days, not all are shown here) gives indication that the structure on which we are focusing is a cyclonic eddy, which seems similar to the eddies addressed in Testor et al. [2005.a]but differs to those studied by Testor et al. [2005.b]and Isern-Fontanet et al. [2004].It is particularly unexpected to observe that a maximum of salinity, reaching 38.4 psu (Fig-5, Left), is associated to this eddy, which is colder than the surrounding waters.

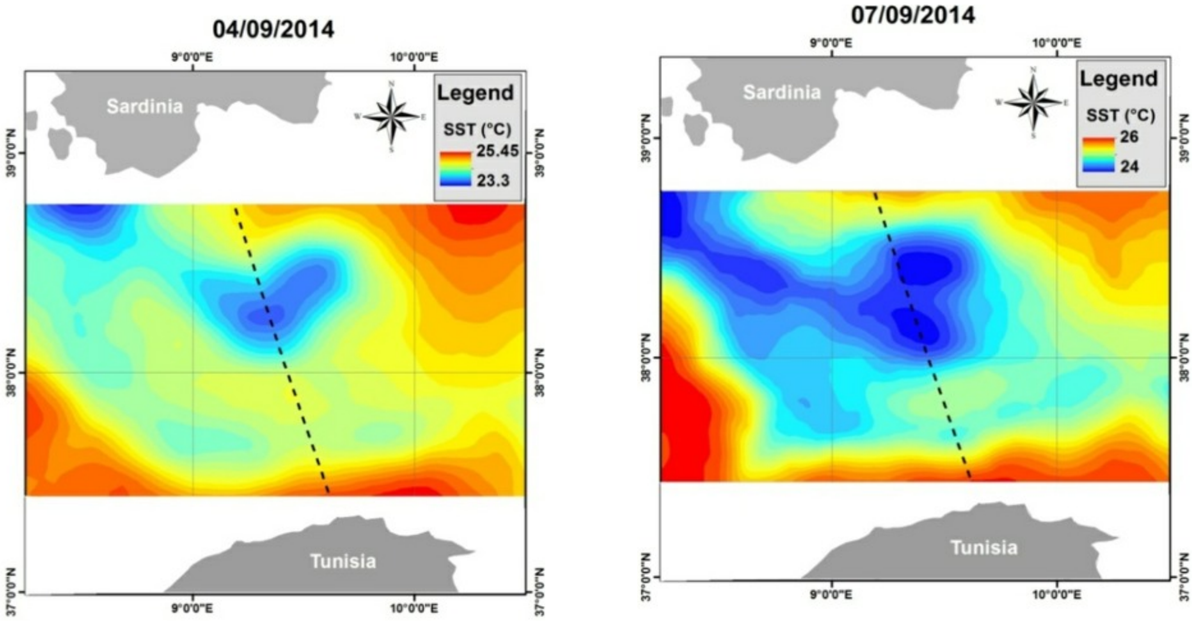

Fig.4 *SST (°C) obtained by analysis of satellite radiometers data (MyOcean data, Left: 4 Sept. 2014, Right: 7 Sept.2014)*

If we admit, that relatively colder waters in the area of interest are necessarily of an Atlantic origin, one would expect a fresh water in the center of the eddy, but it is not the case, here. As we will see later, in-situ glider data will be very useful to understand this hydrological situation.

Furthermore, the map of Surface Chlorophyll Concentration (Fig-5, Right), deduced from satellite remote sensing ocean color, shows a maximum in the center of the eddy, exactly where the temperature is 23.35°C. Thus, there are reasons to believe that our cyclonic eddy generates an upwelling that bringsa nourishment in suspended matter from the sub-surface layer to the surface. This is confirmed by the hydrologic in-situ data acquired during the same time by the glider.

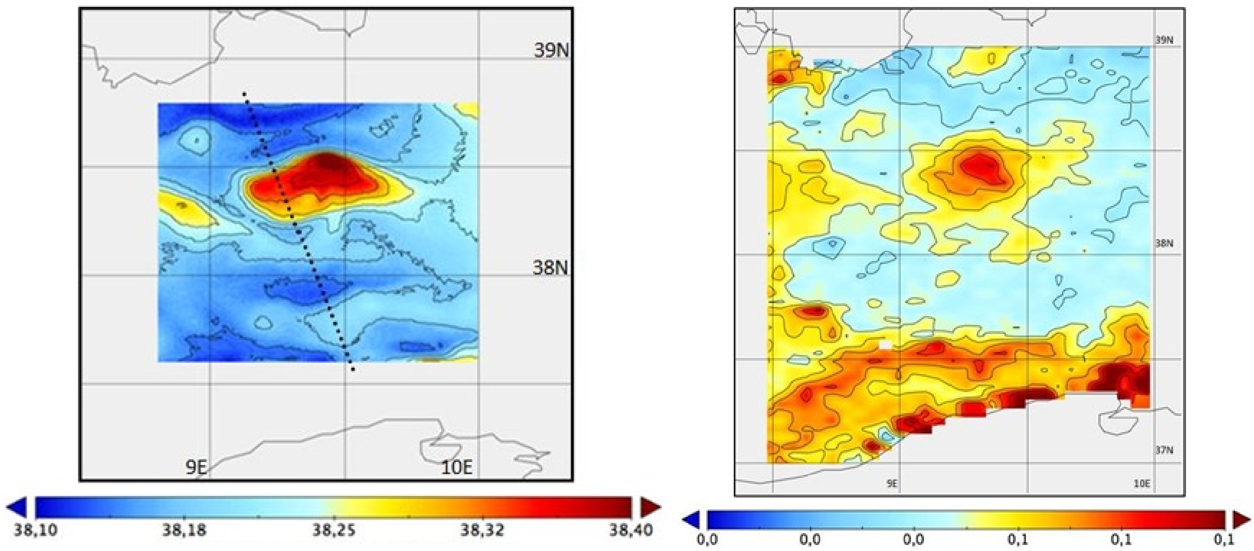

Fig. 5 *Left :Interpolated Chlorophyll Concentration in mg/m^3 produced by GOS-ISAC (Rome) from MODIS-Aqua and NPP-VIIRS Sensors using MedOC3 algorithm, 7 Sept.2014. - Right :Analyzed Sea Surface Salinity (daily averaged) obtained by 3-D hydrodynamic model (NEMO) on a horizontal grid of 1/16° (MyOcean product, 7 Sept. 2014).*

Let's go back to the vertical section of temperature (Fig-2, Left) and salinity (Fig-2, Right). At about 38.15°N (highlighted in the figure by the white circle), we observe an outcropping of the isotherms, which starts at about 50m depth. The in-situ temperature at the surface corresponds to the temperature observed in the center of the eddy (23.5°C) using IR data.

The suspected existence of vertical motion is confirmed by the shape to the isohalines in Fig-2 (Left), within a subsurface layer ranging between -20m and -50m and at the vicinity of 38.2°N (highlighted by a blue ellipse).Consequently, it is demonstrated, from the joint analyses of in-situ and satellite data, that the cyclonic eddy (that seems to be a meander of the AC) generates an upwelling, which, in turn, brings salty water to the surface (38.3 - 38.4 psu), associated with relatively high concentration of chlorophyll. Dynamically, the eddy pumping process is generated by the azimuthal acceleration prevailing around the center of the eddy [BuongiornoNardelli, 2013].

4. Conclusion

This analysis shows the relevancy of the multisensor approach for addressing comprehensively the hydro-biological meso-scale processes that occur in the Channel of Sardinia. It is demonstrated, from the joint analysis of glider, satellite data and 3-D model outputs, how a cyclonic eddy can generates significant vertical motion, which brings salty water to the surface (38.3 - 38.4 psu), associated with relatively high concentration of chlorophyll. The analysis must be pursued in order to quantify the magnitude of the vertical velocities involved in the process, for instance, using the semi-geostrophic Omega equation and altimetric data [Buongiorno Nardelli, 2013].

5. Acknowledgments:

PERSEUS in Funded by the EU under FP7 Theme "Oceans of Tomorrow" OCEAN.2011-3 Grant Agreement No. 287600.JERICO Project(Towards a joint European research infrastructure network for coastal Observatories) has received funding from the EU (FP7/2007-2013) under grant agreement n° [123456].

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AlborEx: a multi-platform interdisciplinary view of Meso and Submesoscale processes

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Abstract

An intensive multi-platform and multidisciplinary experiment was completed in May 2014 as a part of PERSEUS EU funded project, lead by CSIC and with strong involvement of SOCIB, OGS, CNR, WHOI and McGill U. This unique process-oriented experiment in the Eastern Alboran sea (ALBOREX), conducted during 8 days, included 25 drifters, 2 gliders, 3 Argo floats, one ship and 50 scientists. The experiment was designed to capture the intense but transient vertical motion associated with mesoscale and sub-mesoscale features, in order to fill gaps in our knowledge connecting physical process to ecosystem response.

Keywords: gliders, Argo, drifters, fine scale structures, vertical motion

1. Introduction

Vertical motion associated with mesoscale and submesoscale features plays a major role in the exchanges of properties between the surface and the ocean interior ((Klein and Lapeyre 2008). Modelling studies of frontal regions suggest that vertical exchange is enhanced at density fronts (Lévy et al 2001; Mahadevan and Tandom 2006). Significant uncertainty still exists, however, in our understanding of the net effect of mesoscale and submesoscale variability on biochemical tracer redistribution and the consequent marine ecosystem response.

In order to monitor and establish the vertical exchanges associated with fine-scale structures, multi-sensor synoptic observations need to be collected (Ruiz et al., 2009; Pascual et al., 2013). In situ systems, including R/V (CTD, water samples, ADCP), gliders and drifters have to be coordinated with satellite data to provide a full description of the physical and biochemical variability. The observational approach must be integrated with numerical simulations both realistic and process oriented studies.

In the Western Mediterranean, the transition region between the Alboran Sea and the Algerian sub-basin to the east is characterized by strong fronts (1.5 sigma-t differences and mostly governed by salinity) and mesoscale anticyclonic eddies.

In this study, we present the results of ALBOREX, a multi-platform and multi-disciplinary experiment as part of PERSEUS EU funded project (SubTask 3.3.4, see participants in Table 1) in the Eastern Alboran Sea. The final goal was to monitor and establish the vertical exchanges associated with mesoscale and submesoscale (e.g fronts, meanders, eddies and filaments) and their contribution to upper-ocean interior exchanges.

2. Material and Methods

A synoptic multi-sensor experiment was designed and conducted onboard SOCIB coastal vessel between 25 and 31 May 2014 in the eastern Alboran Sea (Western Mediterranean). *In situ* systems, including gliders, drifters and Argo floats were coordinated with satellite data and modeling simulations to provide a full description of the physical and biochemical variability. Two high-resolution grids were sampled with the ship (area covered 40 km x 40 km, See Figure 1). At each station one CTD cast and water samples for Chl and nutrients analysis were collected. Additional ADCP data was registered in continuous mode. Two gliders crossed an intense front. Details of the sampling for each of the platforms are given in Ruiz et al. (2015).

Table 1. *Participants involved in the Alborex experiment.*

INSTITUTION	CONTRIBUTION
CSIC (ES) Ananda Pascual; Benjamín Casas; Ana Massanet; Félix Magirier; Margarita Palmer; Joaquín Tintoré; Simón Ruiz; Alejandro Orfila; Antonio Tovar; Emma Heslop; Evan Mason; Miguel Martínez; Juan Carlos Alonso	Lead partner Scientific and technical coordination Gliders Drifters Argo Biochemical samples Remote sensing Modelling (ROMS, delayed time)
SOCIB (ES) Joaquín Tintoré; John Allen; Carlos Castilla; Pau Balaguer; Mélanie Juza; Marc Torner; Temel Oguz; Charles Troupin; Irene Lizarán; Kristian Sebastián; Baptiste Mourre;	Ship Glider facility Modelling (ROMS operational, Biochemical) Data management
OGS (IT) Pierre Poulain, Giulio Notarstefano	Drifters, Argo Drifter deployment strategy and data analysis
CNR (IT) Antonio Olita	Glider deployment strategy and data analysis Ocean color images
WHOI (USA) Amala Mahadevan	Physical-Biochemical modelling
McGill U (CANADA) Mariona Claret	Physical-Biochemical modelling

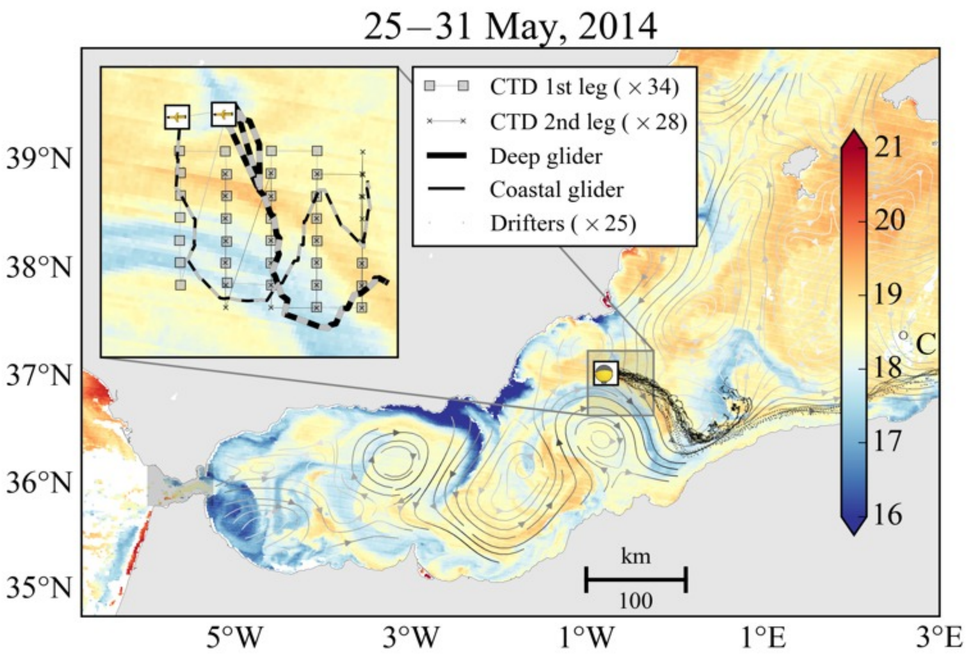

Fig. 1 *SST (Modis-Aqua) for 29 May 2014 with CTD cats, glider and drifter tracks during Alborex experiment. The isolines correspond to Absolute Dynamic Topography from gridded altimeter fields (CMEMS-SLTAC).*

3. Results

The Eastern Alboran Sea is characterized by strong gradients in salinity due to the confluence of recent Atlantic water (recent AW) entering from Gibraltar and the more saline resident Mediterranean Water, which is referred here as old Atlantic Water (old AW). During the Alborex experiment the thermosalinograph measured differences in salinity of about 1.5 in less than 5 km (Ruiz et al., 2015).

T-S diagram for survey 1 (Fig. 2) confirms the presence of both type of waters, not only at the surface but also at deeper levels.

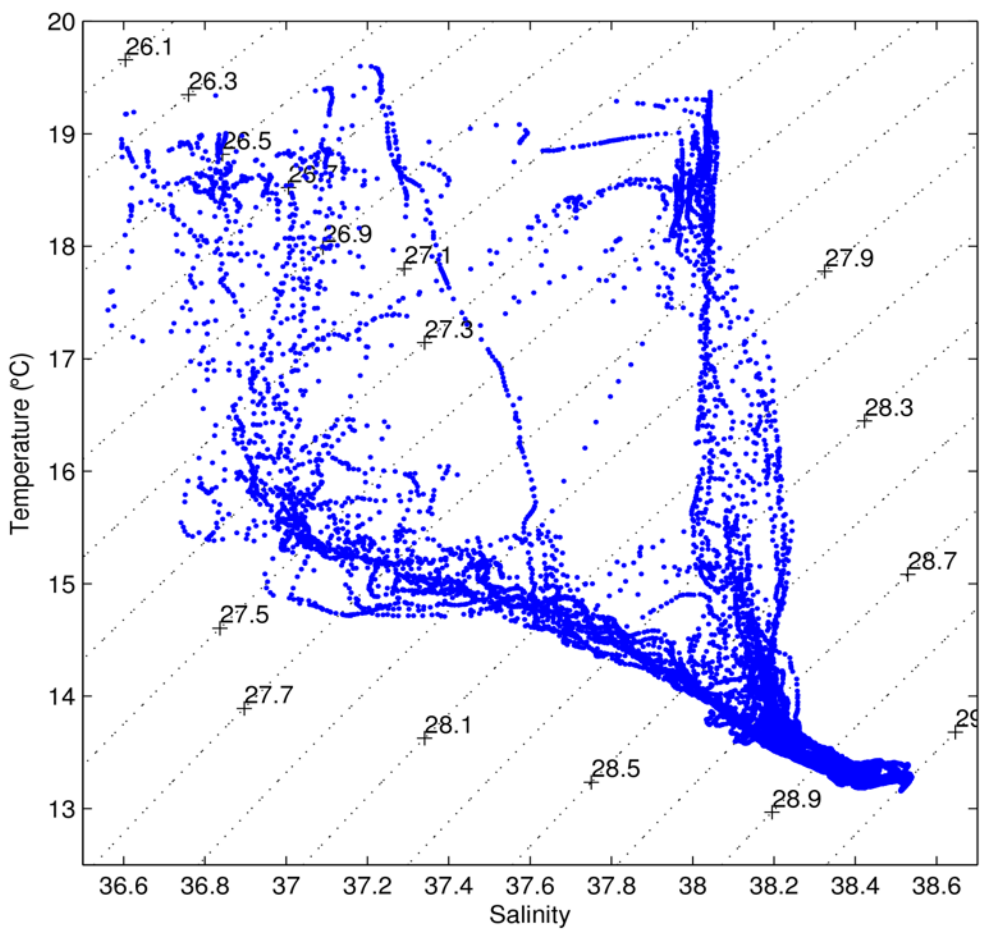

Fig. 2 *T-S diagrams from survey 1.*

The drifters followed coherently an anticyclonic gyre. Near real time data from ADCP showed consistent patterns with currents up to 1m/s (2 knots) in the southern part of the sampled domain. This is almost a factor 2 larger than the magnitude of derived surface currents from standard altimetry gridded fields. Further, altimetric fields failed to properly detect the extension of the front due to limited resolution.
Gliders were able to sample at high-resolution the frontal zone. The coastal glider was configured to collect hydrographic and biochemical data at about 0.5 km while resolution of data from the deep glider was of about 1 km along track. Figure 3 shows the temperature and fluorescence from DG.

Small scales (less than 10 km width) filaments subducting are observed in different parts of the sampled area.

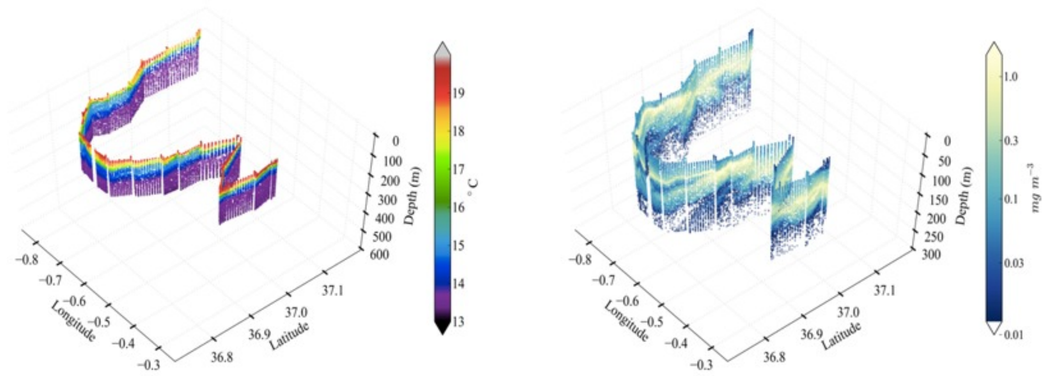

Fig.3 *Temperature (left) and chlorophyll (right) concentration collected by deep glider.*

4. Conclusions/Discussion

The analysis of data collected by ALBOREX multi-platform experiment will provide new insight on the potential mechanism governing the upward/downward motion in frontal zone. The quasi-geostrophic theory can partially explain vertical exchanges at the mesoscale, however at smaller scales (submesocale), with Rossby number higher than 1, other mechanisms such as frontogenesis and mixed layer instability may play an important role and need to be investigated in detail. Moreover, the effect of winds on vertical motion (Ekman pumping contribution) also should be considered and quantified. Further steps consist in isolating mechanisms using a Process Study Ocean Model that would aim to resolve vertical transport at the front.

This intensive multi-platform and multidisciplinary experiment is an example of the new integrated and quasi real time approach to ocean observation thanks to joint and collaborative efforts of scientists and technicians from diverse international institutions. The Alboran Sea is indeed an ideal test site for studying 3D meso and submesoscale processes, with intense fronts impacting biogeochemistry. Future studies will have to expand the observing capabilities with new high-resolution interdisciplinary experiments integrating diverse multi-platform approaches with numerical models. These experiments will have to resolve a range of scales and will contribute to enhance our understanding of intense but transient vertical exchanges associated with mesoscale and sub-mesoscale features, in order to fill gaps in our knowledge connecting physical process to ecosystem response.

5. Acknowledgements

The Alborex experiment was conducted in the framework of PERSEUS EU-funded project (Grant agreement no: 287600) with substantial support from SOCIB. Glider operations were partially funded by JERICO FP7 projects. We would like to thank all the crew on board R/V SOCIB for their efficient collaboration during the Alborex experiment.

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"Integrated Marine Research in the Mediterranean and the Black Sea"

Observing the origin of Levantine Intermediate Water: A design study for a hydrographic mooring

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Abstract

The origin of the Levantine Intermediate Water is suggested by a few studies, but its formation was seldom observed in-situ. When direct observations exist, they are too sparse in space and time to make conclusions about the location, volume, and annual variability of the formation. This study evaluates the mixed layer properties of those historical temperature and salinity profiles, as well as model and satellite data, in order to provide a location for a fixed-point hydrographic mooring. If deployed at the site (29.525°E; 35.2°N), the monitoring of LIW formation in the Rhodes Gyre should be maximized.

Keywords: Rhodes Gyre, Convection, LIW formation

1. Introduction

In recent years, the density of oceanographic observations of in-situ quantities has increased throughout the Mediterranean. However, some regions remain poorly sampled, as described in a recent Perseus report (D3.7: Report on operation and data analysis from R/V monitoring for MSFD). One particular region identified as a "gap" is the Rhodes Gyre (RG), where numerous studies suggest that the Levantine Intermediate Water (LIW) is formed. Yet LIW plays a significant role in the thermohaline circulation of the Mediterranean, as the water mass is found throughout the whole basin and plays, among others, an important role in the preconditioning of deep water formation.

If basin-scale statements are generally well accepted, the LIW formation's sites and mechanisms are very less documented. Most authors agree on the fact that LIW formation is a seasonal phenomenon (during late-winter or early-spring), but misunderstandings come from its interannual variability in location and strength. Before its formation, during summer, the surface layer is pre-conditioned (warm and salty dense water). As winter comes, it is cooled and gets saltier, which tends to break the static equilibrium. Convection then happen, launched during cold atmospheric events: a mixed-layer of 200-400 meters deep is created locally, mixing Levantine Surface Water, Atlantic Water and sometimes remaining LIW.

The phenomenon was observed in the Levantine basin during measuring campaigns: Ovchinnikov (1984), Sur (1992) or POEM campaigns (Robinson et al., 1991), etc. And recent technical improvements provide us with new means to observe it: Argo float profilers, altimetry and chlorophyll detection by satellite. Satellites (like ERS and TOPEX ones) allow the study of the sea dynamics by altimetry and can be a tool to track mesoscale features (Isern-Fontanet (2006)). The observation of surface chlorophyll concentration revealed that the Rhodes gyre (D'Ortenzio et al. (2009)) is an area of intermittent blooming of phytoplankton which supports the thesis of seasonal upwelling.

This document describes the hydrographic study lead at the OC-UCY to find the best location of a fixed oceanographic mooring designed to better understand the preconditioning and the spatial and temporal variability of LIW formation. The location was computed as the most probable site of convection events, from in-situ, satellite and model data. In order to address spatial variability, data from such a mooring must be combined with other tools, like floats, ships, gliders, remote sensing, and numerical simulations. Many of these tools are already active in this area and could be merged with observations from the future mooring.

2. Materials and methods

To carry out this study, in-situ observations were analyzed to find the optimal position of the fixed mooring regarding LIW formation sites. The raw temperature and salinity profiles were extracted from the MyOcean In-situ Database (http://www.myocean.eu). Profiles from floats, drifters, gliders, moorings and cruises between 1990 and 2013 were downloaded. The coverage of the RG region is shown in Fig.1.

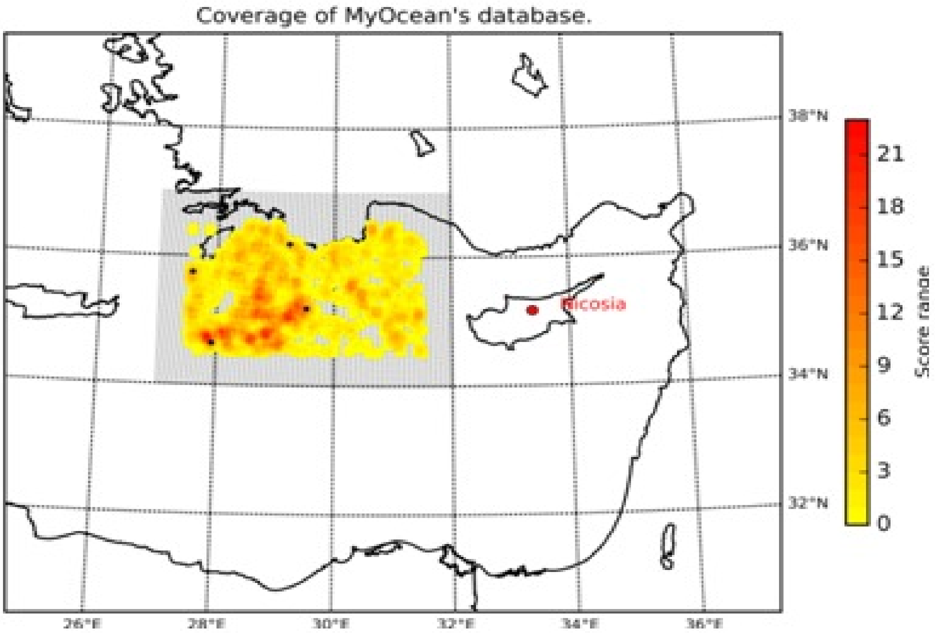

Fig.1 *Coverage of MyOcean in-situ database for years 1990-2013, winter T-S profiles (Dec-April).*

For model considerations, we exploited MyOcean's "Mediterranean Sea Physics Reanalysis." The files were downloaded with the following characteristics: daily mean, at resolution 1/16^{o}, from -1428m to surface, from 01/12 to 30/4, 2005 to 2013, [26-35]°E and [32-37]°N.

Chlorophyll A concentrations were obtained from the analysis of ocean colour measured by the AquaMODIS satellite. The data were downloaded from NOAA's server (ERDAPP) and extracted from 01/12 to 05/5 of each year between 2003 and 2015. The type of data used was L3m (SMI), with a spatial resolution of 1/25° (~4 km) and a time resolution of 8 days.

A "Temerature-Salinity (TS) descent" method was used to sort the profiles from both in-situ and model datasets. Starting from the surface, the sorting routine loops over the depth's index. For each new depth D, it checks that, within the layer between surface and D, the mean values of T and S are in a predefined range (we used the ranges [15;18] °C for T and [38.9;39.3] psu for S). This way, we select profiles with surface water masses respecting LIW characteristics. The routine also checks that the T and S values at depth D are close to their respective upper mean values (closer than 0.10 °C for T and 0.01 psu for S from their mean value between surface and D-1). Thus we track mixed-layers, along which we have nearly constant T and S values. We assume that a minimal depth of mixed-layer is necessary to lead to LIW formation (we most often selected mixed-layers deeper than 100 m).

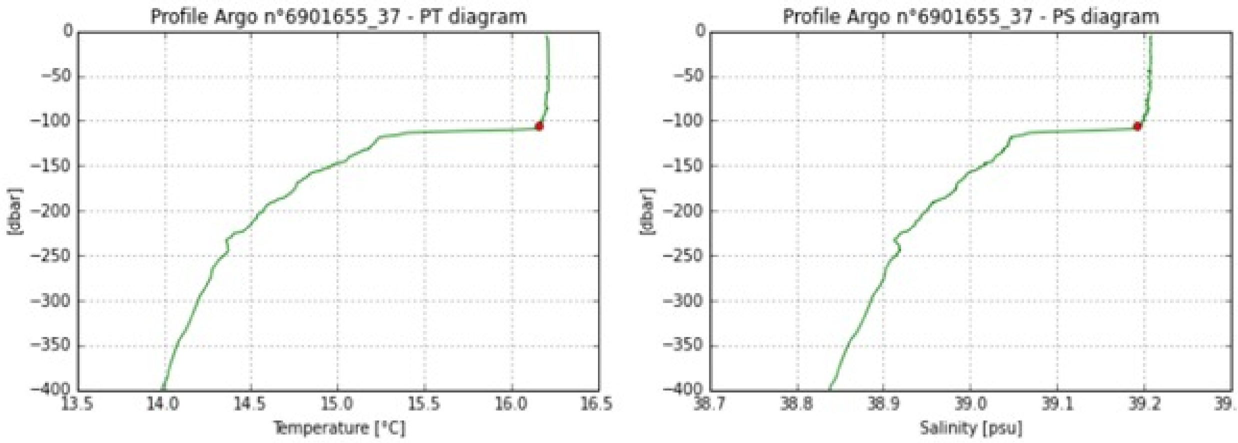

Fig.2 *An example of mixed-layer, identified on temperature (left) and salinity (right) profiles by the TS descent method. The red dot marks the bottom of the mixed layer*

Convection episodes induce both local minima in the surface chlorophyll A concentration (Houpert, 2013) (due to the dilution of the phytoplankton in the mixed layer, with vertical velocities reaching 15 cm/s in the Gulf of Lions) and prepares a spring bloom a few weeks or days later as nutrients are brought up to the surface by the mixing.
As concentrations are very low in the Levantine basin, to get a better visualisation, we studied its variance over each whole winter instead of local extrema on weekly mean maps of chlorophyll A concentration. A grid of a 1/25° step was filled with the variance of each winter. The variance is increased both by minima during convection episodes, and by maxima, expected to be stimulated by the nutrients brought to the surface during the convection. For each winter, local blooms were defined by variances greater than a threshold of 0.05 mg/m^3.

3. Results

To present our in-situ and model analysis, we gridded the Levantine basin at a 1/16^o step. Each point of that grid has a score, which is implemented according to the number of profiles showing LIW formation and located around that point (within the radius of decorrelation of 1/5^o). As the number of tracked LIW events is largely correlated to the number of available profiles, for in-situ datasets, we calculated the "normalised score", which is the score divided by the total amount of observations within the radius of decorrelation surrounding each point of the grid. Areas with high scores and normalised scores are the most probable areas of formation of LIW (Fig. 3).

The model analysis offers a larger coverage. It demonstrated the high spatial interannual variability of the LIW formation (example of year 2009 in Fig.3), but confirmed the RG region as a preferred site.

The blooms computed from the variance of chlorophyll A concentration over the winters 2004 to 2015 enlighten a region (namely, the RG) of intermittent blooming, very similar to the one obtained by D'Ortenzio et al. (2009) (Figure 4). This was taken into account in for the choice of the location of the mooring.

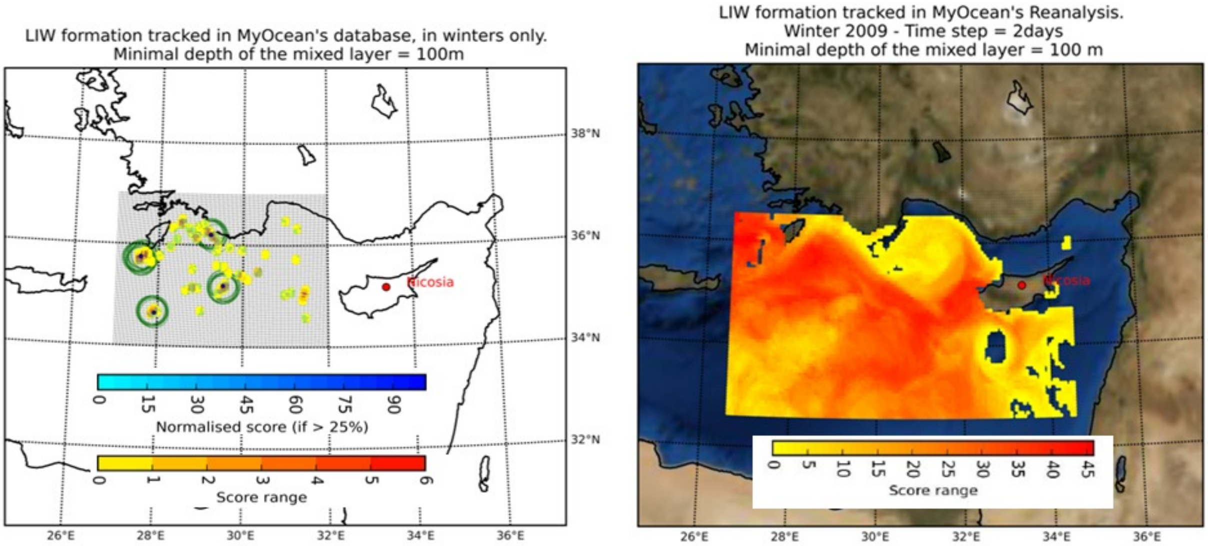

Fig. 3 *Positions of LIW mixed layers greater than 100 m detected in-situ. The grid’s score is shown by a colour scale varying from yellow (0) to red (max). Its normalisation varies from cyan (0) to deep blue (1). Most relevant regions are circled in green. (left). LIW formation occurrence based on LIW mixed layers greater than 100 m in MyOcean re-analysis: year 2011 (right).*

Bloom areas (2004-2014)

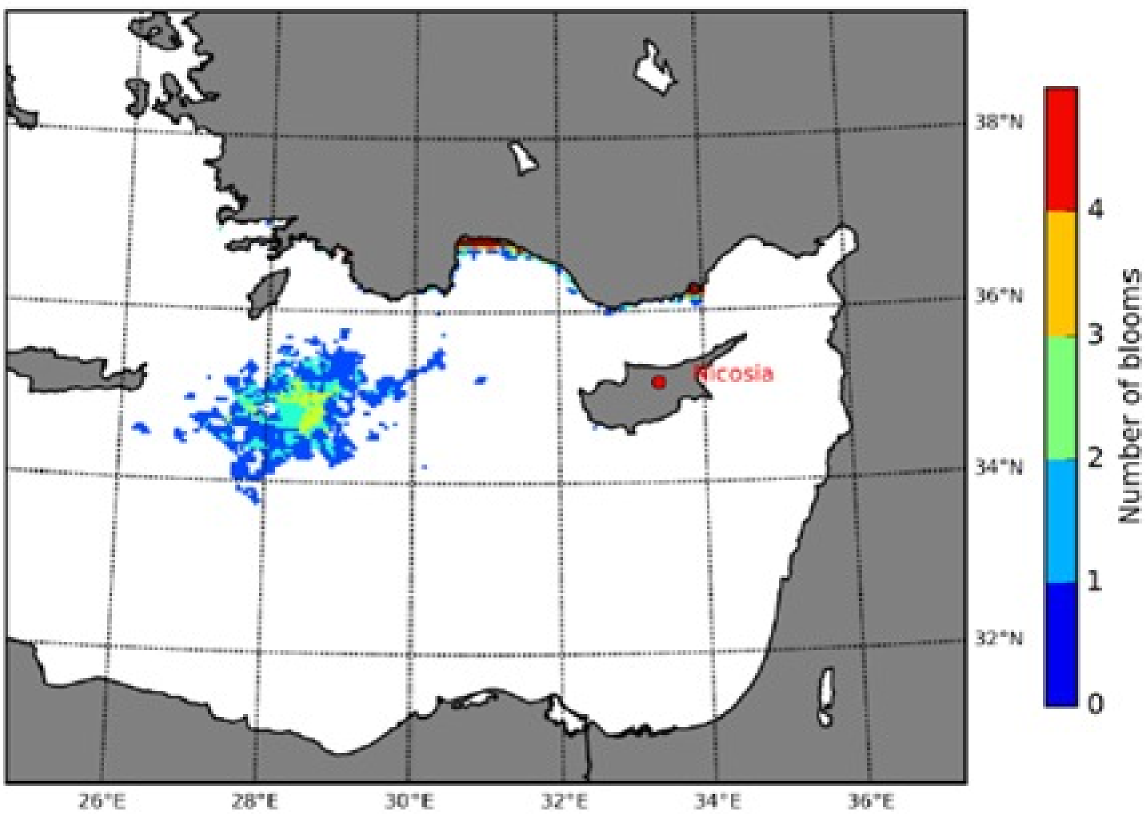

Fig. 4 *Number of blooming years per area, computed from the variance of chlorophyll A weekly means (2004-2014).*

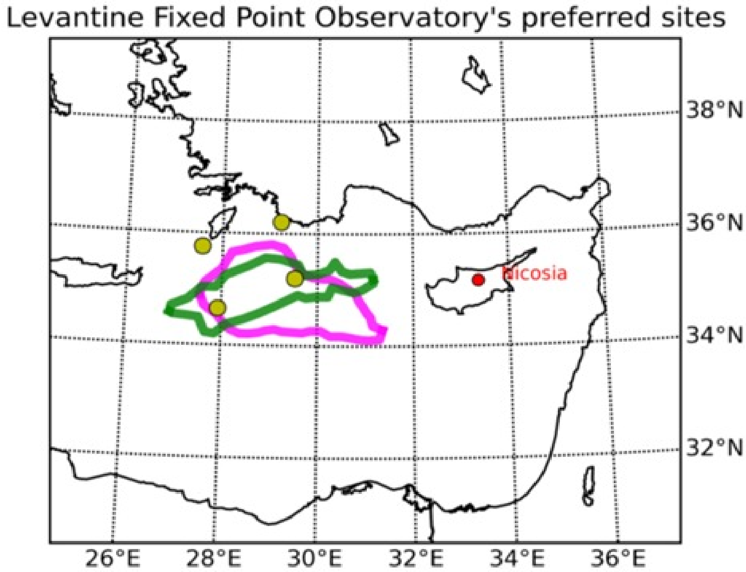

Fig. 5 *Map of suggested sites for LIW fixed point mooring. Preferred station is the lower right. Pink line is outline of region where float data suggest LIW is closer than 100 m from the surface (Hayes et al., 2014). Green line is outline of Chlorophyll-a blooming region (D'Ortenzio & al., 2009).*

4. Conclusion

Thanks to the results above, we could draft a spatial and temporal description of the LIW formation.The temporal behaviour was computed from our model study: LIW formation is mostly observed in February-March. This is common for all the winters considered in the study (2005 to 2013, example of 2008 in Fig. 6).According to the spatial considerations, four sites (Fig. 5) were identified for the Levantine Fixed Point Observatory: with the most preferred at (29.525°E; 35.2°N), and a depth of 2750 m. A deployment at this location would improve the monitoring of the LIW formation, its preconditioning, and correlation with other features (atmosphere, phytoplankton, etc.)

5. Acknowledgements

This research has been partially supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Methods to analyse Vessel Monitoring System data

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Abstract

The objective of this work was to apply methods for the analysis of Vessel Monitoring System (VMS) data with the prospect that these could constitute a common analysis approach for the treatment of such data. During the implementation period, different approaches were introduced to achieve these goals and several methods were used for the analysis of VMS data. VMS data were combined with other parameters such as bathymetry, presence/absence of species etc. VMS data were analysed for the western (Spain), central (Italy) and eastern (Greece) Mediterranean Sea basins. The results of VMS analysis is important information for the scientists and constitutes a basic cartographic background for studies related to conservation status of fishing areas, identification of migration patterns and movement strategies of the fishing fleet and identification of fishing grounds.

Keywords: VMS, fishing effort, fishing grounds, migration patterns

1. Introduction

The objective of the current work refers to how VMS data can be analysed and how the results can be combined with other biotic and abiotic parameters. The achieved output meets the requirements of the Common Fishery Policy (CFP) for managing European fishing fleets and for conserving fish stocks. The proposed methods produce high quality estimates of the fishing effort and the fishing activity of the fleet that meet another direction of CFP which refers to "reduce unwanted catches and wasteful practices to the minimum or avoid them altogether". The fishing effort estimates constitute necessary information which must be available for management purposes. From the scientific point of view, "good quality" estimates of fishing effort are required in order to be used in management plans for the operation of different fishing gears and for modelling purposes. Moreover, in the framework of Data Collection Framework (DCF) there is an obligation for all Member States to analyse VMS data and produce specific indices related to the distribution of the fishing activities (DCF indicator 5), aggregation of the fishing activity (DCF indicator 6) and areas that are not impacted by mobile bottom gears (DCF indicator 7). The cartographic backgrounds can be used as a "fishery status component" in a general model and according to PERSEUS targets.

More generally, vessel monitoring system (VMS) is a satellite-based monitoring system which at regular intervals provides data to the fisheries authorities on the location, course and speed of vessels. VMS is nowadays a standard tool of fisheries monitoring and control worldwide, but it was the EU which led the way, becoming the first regions of the world to introduce compulsory VMS tracking for all the larger boats in its fleet. The EU legislation requires that all coastal EU countries should setup systems that are compatible with each other, so that countries can share data and the Commission can monitor that the rules are respected.

2. Materials and methods

VMS data analysis can be explained through two modules. The first is the basic part concerning the common methodological procedures for VMS data analysis. The aim is to estimate fishing effort indicators and to define common spatial references for visualization. The methodological steps are the primary analysis which includes the quality control of data (duplicated records, vessel positions on land, implausibly high speeds, headings outside compass range), the data enhancing (integrate legislation and bathymetry, interpolation), métier identification (combine VMS data and logbooks), the estimation of fishing effort indicators (Days at sea, Days*GT, Days*KW, fishing hours) and visualization (spatial cell size, geographical coordinate system, etc.) (Kavadas & Maina, 2012; Russo et al., 2014). The second module is about fishing effort applications. The aim is to use the output of the fishing effort estimates to various implementations satisfying National and European requirements. In the framework of a PhD thesis supported by PERSEUS project, the applications were introduced are the identification of fishing grounds for the target species of a gear (e.g. bottom trawl), the identification and mapping migration spatiotemporal patterns of the investigated fishing fleet and the use of VMS data from trawlers and purse seiners to Multi Criteria Decision Analysis to estimate fishing pressure index from small scale fisheries.

Concerning the first module it will be useful to emphasize that while different approaches and tools have been applied and tested by each partner, a common methodological workflow was defined and applied to the different national VMS datasets. Basically, the workflow is aimed at refining the information provided by VMS data, even reducing noise, and enhancing it by crossing VMS data with external sources of information such as bathymetry and Logbook data. While the main output of the workflow is represented by Fishing Set Positions (FSP) with related information about vessel characteristics (overall length of vessel, engine power KW, etc.) and used gear, accessory outputs can be produced in terms of descriptors/indexes of fishing pressure. It is important to stress that, while the different methods and tools are characterized by adjustments and are customized on the basis of the available data (with can therefore differ in terms of format, structure and issues), the rationale defined by this workflow is already respected. In this way, the workflow allows obtaining preliminary outputs, which can be used for different and more advanced analyses.

Concerning second module, the first application is about the identification of fishing grounds for the target species of a gear (e.g. bottom trawl). In this application, the potential habitats of the most important commercial species and vessel monitoring system data (VMS) from trawlers were modelled in order to identify fishing grounds (Maina et al., 2014). In this work, sixteen target species from trawlers were studied. The methodology is based on: (a) the assessment of the probability of species presence using Generalized Additive Model (GAM), (b) the estimation of a threshold of species presence using the Receiver Operating Characteristic analysis (ROC), (c) the combination of presence/absence model and the estimated fishing effort from trawlers using VMS data and (d) the identification of the main fishing grounds using Hot Spot analysis.

The identification and mapping migration spatiotemporal patterns of an investigated fishing fleet was included in the second module. In this analysis, VMS data were used to identify and map spatiotemporal migration patterns of bottom trawlers during the period 2010-2011 in the Aegean Sea (Maina et al., 2015). The preliminary exploration of patterns is based on the combination of VMS signals and fleet's registration ports distributed in nine fishing areas of the Aegean Sea. The identification and visualization of migration patterns were based on the spatial distribution of Fishing Effort (FE) and Anselin Local Moran's I method. The transmitted signals were analyzed by vessel, fishing area and registration port and were combined with FE on annual and monthly scales.

In the context of the Maritime Spatial Planning Directive and with the intention of contributing to the implementation of a future maritime spatial plan, it was decided in the framework of the second module, to analyze data from the small scale coastal fisheries sector of Greece and estimate the actual extent of its activities, which is largely unknown to date. To this end, we identified the most influential components affecting coastal fishing in terms of its distribution and intensity: fishing capacity, bathymetry, distance from coast, Sea Surface Chlorophyll (Chl-a) concentration, legislation, maritime traffic activity, trawlers and purse seiners fishing effort and no-take zones. By means of Multi-Criteria Decision Analysis (MCDA) conducted through a stepwise procedure, the potential fishing footprint with the corresponding fishing intensity was derived (Kavadas et al., 2015). The method provides an innovative and cost-effective way to assess the impact of the, notoriously hard to assess, coastal fleet. It was further considered how the inclusion of all relevant anthropogenic activities (besides fishing) could provide the background needed to plan future marine activities in the framework of Marine Spatial Planning (MSP) and form the basis for a more realistic management approach.

3. Results

Common methods were applied to estimate fishing effort from bottom trawlers and purse seines at an annual and monthly scale for each case study (Fig 1). In addition, the analysis of spatiotemporal patterns of fishing pressure on bathymetric zones was performed for the western (Spain- Balearic islands) and eastern (Greece) Mediterranean Sea (Fig 1). Methods that were developed in the framework of the second module were applied for the Greek case study. These methods concerns the identification of fishing grounds for the target species of bottom trawlers, the identification and mapping of migration spatiotemporal patterns of bottom trawlers in the Aegean Sea, the use of VMS data from trawlers and purse seiners to Multi Criteria Decision Analysis to estimate fishing pressure index from small scale fisheries.

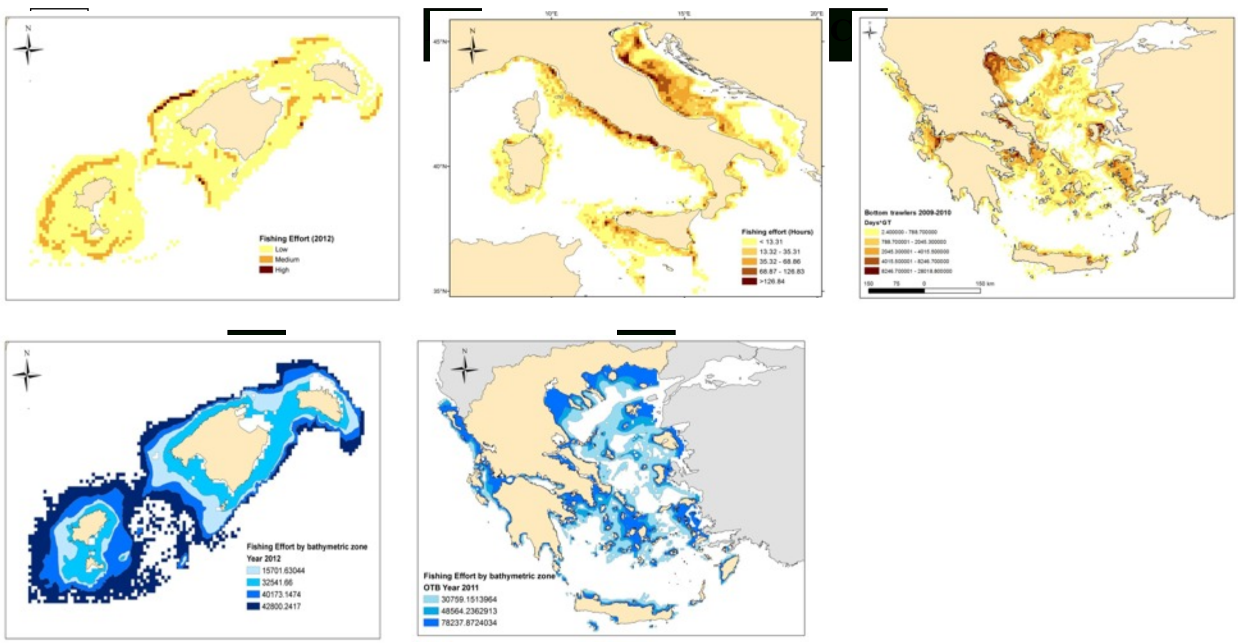

***Fig. 1**: Fishing effort from bottom trawlers in A) Balearic Islands, B) Italy, C) Greece and fishing effort by bathymetric zone in D) Balearic Islands and E) Greece.*

4. Conclusions/Discussion

The proposed methods satisfy scientific and management purposes giving basic information for further analysis and modeling. In addition, the output of the analysis satisfies some basic requirements of CFP not only in the manner to collect data but also to analyze them and give concrete and reliable results about the behavior of the fishing fleet controlled by the VMS. On the other hand, improvements and new approaches are ongoing and can be applied in the framework of a PERSEUS follow up project or other similar projects. The collaboration between partners, the exchange of ideas and the review of several methods that were used by each partner, was fully satisfactory and the people that were involved in this task have enhanced the ways of analyzing the significant information that derived by VMS. All the information that derived from this work referred to a common methodological framework that takes into consideration the specifics of each case study and is available to the PERSEUS scientists in order to fulfill the specific needs of the project. The modules that were developed are also compatible with the Descriptor 3 "Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock" of Marine Strategy Framework Directive (MSFD: 2008/56/EC) especially under the aspect of the level of pressure and fishing activity.

Considering all the above, this is the first time that common methodologies have been established in Europe in an observing system using VMS and by having a direct relevance to MSFD implementation, Marine Spatial Planning, fishing fleet migration strategies, fishing grounds, etc. The data analysis methods and modeling with other biotic and abiotic parameters could also be used as an implementation guide for other European areas.

5. Acknowledgements

This work is part of the ongoing research carried out under the EU FP7 project "Policy-oriented marine Environmental Research for the Southern European Seas"
(PERSEUS, website:http://www.perseus-net.eu)

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Development of a Tool for the identification and assessment of Environmental Aspects in Ports (TEAP)

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Abstract

A new tool to assist port authorities in identifying aspects and in assessing their significance has been developed. Although there is a high percentage of European ports that have already identified their Significant Environmental Aspects (SEA), most of these ports do not use any standardized method. This suggests that some of the procedures used may not necessarily be science-based, systematic in approach, publicly available or appropriate for the purpose of implementing effective environmental management. After analysing the strengths, weaknesses and challenges of the existing techniques, and taking into account the advice of specialists, a computer-based tool (www.esports.cat) has been developed.

Keywords: Significant Environmental Aspects, Environmental Management, Sustainable Development, Port Management

1. Introduction

It has been widely reported that although ports around the world are major centres for the economic development of the areas where they are located, port and shipping activities also pose negative externalities and impacts to their surrounding natural habitats (OECD, 2011; Dinwoodie et al., 2012). It is, therefore, important for those with responsibilities concerning port environmental management to be aware of the issues that are at stake with regards to the environment in European ports (ESPO, 2012).

An effective port environmental management requires awareness and knowledge of its environmental aspects in order to know what is required to be properly managed from the environmental point of view (ESPO, 2011). According to ISO 14001 (2004), an environmental aspect is an element of an organisation's activities, products and services that can interact with the environment. Examples of them are water discharges, emissions to air, or waste generation.

Each port has different environmental aspects depending on the activities that are carried out within the port area. It is highly recommended that port authorities select, from those, the most significant ones, called the Significant Environmental Aspects (SEA). Being aware of the SEA allows a port to focus its time, efforts and resources on those issues with major potential for environmental impact, providing the greatest assurance that the environment will be protected (Puig, 2012). In addition, the establishment of a SEAs identification procedure is one of the requirements and essential tasks for the development and implementation of an Environmental Management System (EMS). Although all the EMS standards provide some advice and criteria on this selection, they also recognise that there is no single, standardised procedure for identifying environmental aspects since each port is unique and each organisation has its own characteristics and distinctive features. Therefore, it may be difficult for some ports to identify and select aspects in a credible and scientific way in line with their activities. This was confirmed with a research conducted by PERSEUS on the Mediterranean and Black Sea ports. For this reason, it raised the need for the development of a method that would assist ports to perform this task in a more reliable manner.

2. Materials and methods

In order to develop the tool, six main tasks were carried out:

- Task 1: Identification of port activities

Since aspects are derived from activities, the initial step was to identify the range of possible activities that are likely to be carried out in a port. A total amount of 35 port activities were identified.

- Task 2: Identification of port environmental aspects

A review of the existing environmental aspects in ports was also conducted. The information was obtained from port web-sites, port environmental or annual reports, and EMS reports of port authorities, marinas and terminal operators. A total amount of 55 aspects was initially compiled. Since this number of aspects was perceived as being over-complex in terms of developing a user-friendly, practicable and pragmatic tool, it was reduced to a final list of 17 aspects (divided in seven categories).

- Task 3: Creation of the relationships between activities and aspects

The next step was the definition of the interactions between the port activities identified in task 1 and the port environmental aspects determined in task 2. For each activity, all the aspects that interact with it were determined. In addition, a weighting was allocated to each aspect.

- Task 4: Definition of the criteria to assess the significance

In order to assess the significance of the aspects, a set of 8 criteria was established such as frequency and duration of the aspect, stakeholders' complaints, etc. They were obtained from an extensive literature review (e.g. Easibind, 2012), including best examples of ports that provide their criteria, and the EMS standards advice (EC, 2009; ISO, 2004), among others.

- Task 5: Establishment of the weighting of the criteria responses

For each criterion, several possible responses were established, with an associated weighting, based on the significance of the impact generated on the environment.

- Task 6: Creation of the connections between aspects and criteria

Since not all the criteria are applicable to all the aspects, an assessment of which criteria have influence on each aspect was carried out by creating a table of the interactions between them.

3. Results

In order to obtain the results, 5 steps have to be carried out, as summarized in Figure 1:

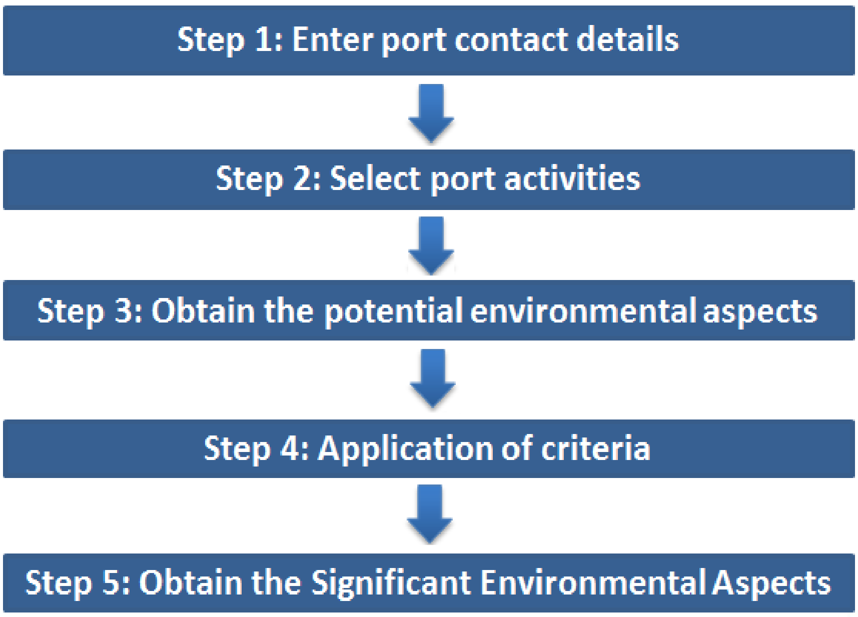

Fig. 1 *TEAP steps needed to obtain the SEA.*

Anyone willing to use the tool has to enter to the website www.eports.cat. Initially, the respondent has to enter the contact details. All this information is confidential and only the user of the tool will have access to his/her results. Once the contact details have been introduced, the respondent has to select the activities that are carried out in the port, out of the 35 possible activities. As mentioned before, each activity is associated with several environmental aspects, and therefore, when an activity is selected, the related environmental aspects are activated.

The tool sums the total number of points that have been activated for each aspect, derived from the activities that have been selected, and ranks them accordingly in descending order. As a result, an extensive list of the port's aspects is generated. In order to find out the list of the main environmental aspects that have the potential to be significant for the port, a threshold value has been established within this methodology: the aspects with a score equal or higher than the 50% of the maximum score are selected. This percentage is based on experts' opinions and on other methodologies identified in the literature review (e.g. Autoridad Portuaria de Valencia or Marina Port Vell).

One weakness of the existing methods is that they do not include criteria for the assessment of aspects, whereas this method does. The port environmental aspects obtained in the previous step are reviewed and assessed against the criteria presented before. Each aspect is assessed only with the criteria that apply to it, which is based on the nature of the aspect. Each criterion has generally four or five possible response options, with different weights. An average value for each aspect is achieved, based on the punctuations obtained in the criteria. These values will be used to assess the significance of the aspect, ranking them in descending order, so that the aspects located in the top positions are the ones with a higher significance. It is considered that the aspects with a punctuation of three or more are the Significant Environmental Aspects. The respondent receives an email with these results, together with a list of potential environmental indicators that can be applied to monitor the identified SEAs.

4. Conclusions

Ports and harbours may be located in highly valuable and vulnerable natural areas, hosting endangered habitat and species, and some of them being protected under EU / national / regional / local nature conservation legislation. For this reason, a broad mix of measures has to be applied for the effective management of potential environmental impacts which are directly linked with the Significant Environmental Aspects.

In this paper, the importance of identifying SEAs as an integrated action of the environmental management of a port has been demonstrated. However, the ports that use either one of the established methodologies or its own method and make it publicly available are still a minority. For this reason, a new methodology has been developed, available to all European ports. No matter the size or the commercial profile of the port, since it is applicable to all types, providing specific results for each one.

To develop the methodology, the wide range of environmental activities and aspects existing in ports were identified through an extensive research and review. After identifying the ports' activities and applying a set of criteria, a final list of Significant Environmental Aspects is generated. It is suggested that the tool could assist port managers in identifying the SEAs of their own port area in a user-friendly, practicable and time-effective manner. The use of this methodology could be beneficial not only for individual port authorities but also for the whole port sector.

5. Acknowledgements

The authors acknowledge with grateful thanks the funding from the PERSEUS (EC, 287600) research project as well as the collaboration of the pilot ports and feedback from other EU ports.

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Remote Sensing Algorithm to Identify Dominant Phytoplankton Groups in the Mediterranean Sea: A Tool for MSFD at Basin Scale.

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Abstract

A regionalized version of the PHYSAT method has been specifically developed for the Mediterranean Sea to account for the regional optical properties and the peculiarities of phytoplankton assemblages. This algorithm (hereafter PHYSAT-Med) can be used to identify specific dominant phytoplankton groups, such as nanoeukaryotes, Prochlorococcus, Synechococcus, diatoms, Phaeocystis-like and coccolithophores. Results provided by PHYSAT-Med showed the dominance of Synechococcus versus prochlorophytes throughout the year at a basin level, although nanoeukaryotes were more abundant during winter months. PHYSAT-Med represents a useful tool for the spatio-temporal monitoring of different dominant phytoplankton functional types (PFTs) in Mediterranean Sea.
Keywords: PHYSAT-Med, phytoplankton functional types

1. Introduction

The Mediterranean Sea is the largest semi-enclosed sea on Earth and is considered one of the most complex marine environments where much remains to be known with regard to circulation dynamics, biogeochemistry and biological activity. In the Mediterranean, phytoplankton community reveals a considerable diversity over spatial and temporal scales (Siokou-Frangou et al., 2010) and large dissimilarities in phytoplankton species composition and other microorganisms across the basins have been reported. Picoplankton dominates the oligotrophic Mediterranean waters, whereas regional physical mechanisms enable the coexistence of several microalgal groups within phytoplankton blooms (Siokou-Frangou et al., 2010). An extensive amount of information on the phytoplankton community structure along the Mediterranean coastline is available. On the contrary, longitudinal data based on large-scale investigations in open ocean waters are scarce in the literature (Ignatiades et al., 2009). This lack of measurements can be partly overcome by using new tools, such as remote sensing techniques. During the last decade and based on different approaches, several algorithms are now able to detect phytoplankton functional types (PFTs) or size classes from space (IOCCG, 2014). The PFTs are groups of species that play specific roles in the marine biogeochemical cycles and trophic flows (Le Quéré et al., 2005). One of the methods that enables to detect PFTs from space is the so called PHYSAT (Alvain et al., 2005; Alvain et al., 2008), which was specifically developed to identify the dominant phytoplankton groups from ocean color measurements. Briefly, PHYSAT is a global model applied for oceanic Case I water and is designed to detect satellite pixels in which the dominant groups are nanoeucaryotes, Prochlorococcus, Synechococcus, diatoms, Phaeocystis and coccolithophores. The PHYSAT approach is based on the identification of specific signatures in the normalized water-leaving radiance (nLw) spectra measured by an ocean color sensor. It is described in detail by Alvain et al. (2005). Specific nLw spectra anomalies (in terms of shapes and amplitudes) have been empirically associated to the presence of dominant phytoplankton groups, based on in situ biomarkers pigment observations. However, due to the specific character of phytoplankton assemblages in the Mediterranean Sea and their associated bio-optical relationships that can be affected by continental inputs such as rivers discharge and desert dust events (Santoleri et al., 2008), it is necessary to adapt the PHYSAT method and evaluate its derived results in this specific region. In this work, the previous version of PHYSAT (Alvain et al., 2005) has been modified in order to estimate the most frequent phytoplankton groups in the Mediterranean Sea. The updated version (PHYSAT-Med) has been validated using in-situ measurements collected in different cruises conducted throughout the entire basin. Therefore, the main objectives of this study were: (i) to adapt the original PHYSAT method to the Mediterranean Sea for MODIS satellite datasets; (ii) to validate the new PHYSAT-Med method with in situ measurements and (iii) to evaluate the spatio-temporal patterns of the PFTs in the Mediterranean Sea since July-2002.

2. Materials and methods

The PHYSAT method is based on the identification of specific signatures in the normalized water leaving radiance (nLw) spectra measured by an ocean color sensor (Alvain et al., 2005). This approach considers the analysis of the second order variation in nLw measurements after removal the impact of chlorophyll a variation. PHYSAT-Med has been adapted to the Mediterranean Sea using the MODIS dataset, between July 2002 and April 2015. Figure 1 displays a schematic diagram of the steps followed to adapt PHYSAT-Med (Navarro et al., 2014).

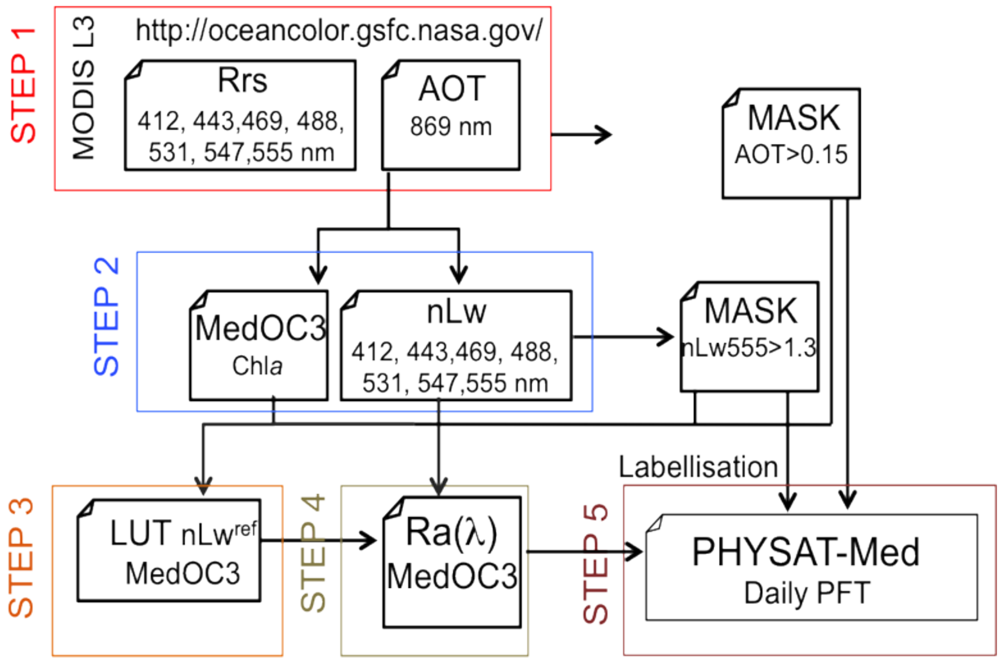

Fig.1 *Schematic view of steps followed to adapt PHYSAT-Med*

Briefly, the first step of PHYSAT-Med was to download all level-3 MODIS daily products (reprocessing version R2013.0) at 4-km resolution acquired from NASA Oceancolor website and remapped on an equi-rectangular grid on the Mediterranean area (−6 to 36° E and 30 to 46° N). The main downloaded products were remote sensing reflectance ($Rs_{(\lambda)}$) at 412, 443, 469, 488, 531, 547 and 555 nm. Since the global chlorophyll algorithm generally leads to a significant overestimation in the Mediterranean Sea (Volpe et al., 2007), the regional MedOC3-Chla algorithm for MODIS images was utilised to estimate the chlorophyll a concentration in the Mediterranean Sea (Santoleri et al., 2008). At the second step, the Rrs was converted to nLw using the nominal band solar irradiance (F_o, in mW cm^{-2} μm^{-1}) for any specific spectral band (λ) for MODIS sensor. Following PHYSAT methodology (Alvain et al., 2005), a new Look-Up-Table (LUT) (Figure 1, step 3) of nLw^{ref} (λ,Chl-a) was empirically generated for the Mediterranean Sea from a large dataset of MODIS Chla and nLw pixels for all daily images comprised within the study period (Navarro et al., 2014). Once the new LUT for the Mediterranean Sea was calculated, the radiance anomalies (Ra(λ), Figure 1, step 4) were computed for all daily MODIS wavelengths and analyzed using the following equation [Ra(λ)=nLw(l)/nLw^{ref} (λ,Chl-a)] for every available wavelengths, where Ra(λ) is an adimensional unit parameter and by definition, this parameter is independent of the chlorophyll a level (being by extension independent of the biomass) and represents hence the second order variation of nLw(λ). The next step was the spectral characterization of phytoplankton groups using the new thresholds described in Navarro et al. (2014). This labelling step relates the Ra spectral patterns to in situ pigment inventories assigning each of them to a particular phytoplankton group (labelling procedure). In addition, a validation experiment was performed using more than 3000 High-Performance Liquid Chromatography (HPLC) measurements collected in the Mediterranean Sea, due to many pigments are specific of individual phytoplanktonic taxa or groups (Jeffrey & Vesk, 1997). Details about the pigment analysis and database can be found in Navarro et al., (2014).

3. Results

Figure 2 shows the monthly climatology of the most frequent phytoplankton groups estimated by PHYSAT-Med method in Mediterranean Sea during the study period (July 2002 - April 2015). At a basin level, the monthly climatological distributions show that Synechococcus is the most dominant phytoplankton group during spring and summer, whereas nanoeucaryotes are more abundant during autumn and winter. In coastal areas other groups proliferate, as it is the case of diatoms with a dominant presence in the northern Adriatic Sea, Ligurian Sea and Gulf of Lion, mainly during spring. The analysis of the monthly distribution of phytoplankton groups reveals a high spatial and temporal variability (data not shown). It is evident that Synechococcus and nanoeukaryotes are the most abundant PFT in the basin over the year, although other phytoplankters can be identified in different subbasins. For instance, during the spring season, diatom blooms are clearly distinguishable in several areas of the Mediterranean, such as the Catalan Sea, the Adriatic Sea, the Ligurian Sea and the Ionian Sea.

The temporal variability of PFTs (Prochlorococcus, Synechococcus, diatoms and nanoeukaryotes) in the Ligurian Sea (Figure 3) was also analyzed and compared with HPLC measurements (pigment ratios) provided for the same sub-basin during certain periods of time at the first optical depth. Figure 3 shows oscillations of the four PFTs during the year, with peaks and minima appearing at different times of the year depending on the group. Prochlorococcus exhibited maxima at the end of the stratification period (normally in October) over several years (Figure 3a). The maxima found by the PHYSAT-Med model were in close agreement with the maxima in the concentrations of the pigment ratio for divinyl Chl-a provided by HPLC, which is indicative of prochlorophytes (i.e. Claustre & Marty, 1995). However, during the stratification period in this region, between July and October, the phytoplankton group identified by PHYSAT-Med as the most abundant was Synechococcus (Figure 3b). This feature also matches the highest values for zeaxanthin (a pigment associated with cyanobacteria, Guillard et al., 1985) measured by HPLC during this period in the Ligurian Sea (Figure 3b). The visual concordance between the results obtained with both approaches also applies to diatoms, as the annual peaks registered by PHYSAT-Med every year during the spring bloom closely resemble the maxima of fucoxanthin given by HPLC (Figure 3c). Finally, the nanoeukaryotes present maxima during winter season, normally around January, although the maxima pigment ratio of 19'-hexanoyloxyfucoxanthin (19′-HF) is achieved during spring–summer seasons (Figure 3d), which can be due to the heterogeneity of this phytoplankton group in terms of species composition.

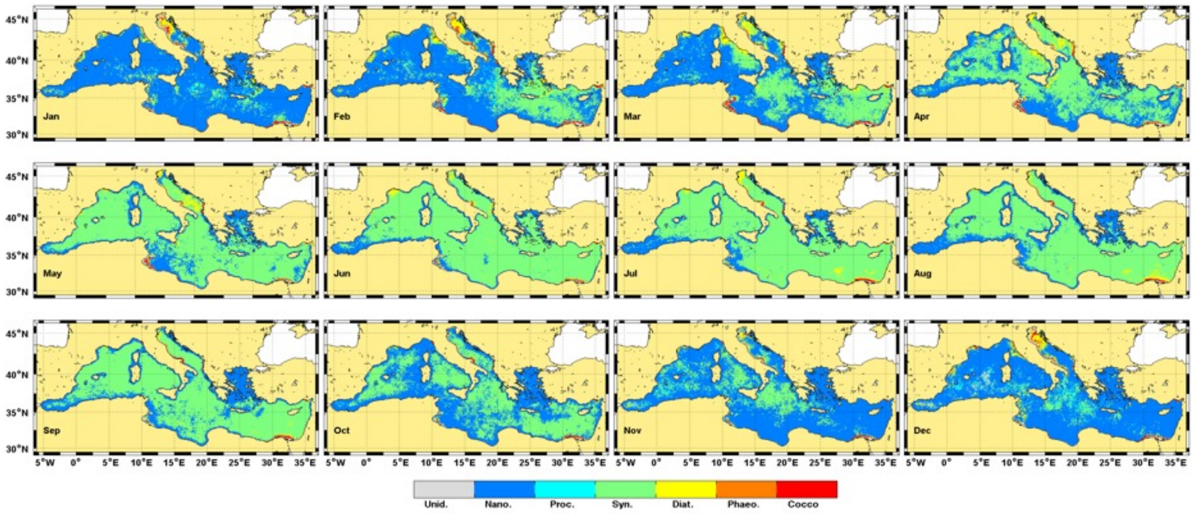

Fig. 2 *Monthly climatology of the dominant phytoplankton group detected by PHYSAT-Med during the study period (July 2002–April 2015).*

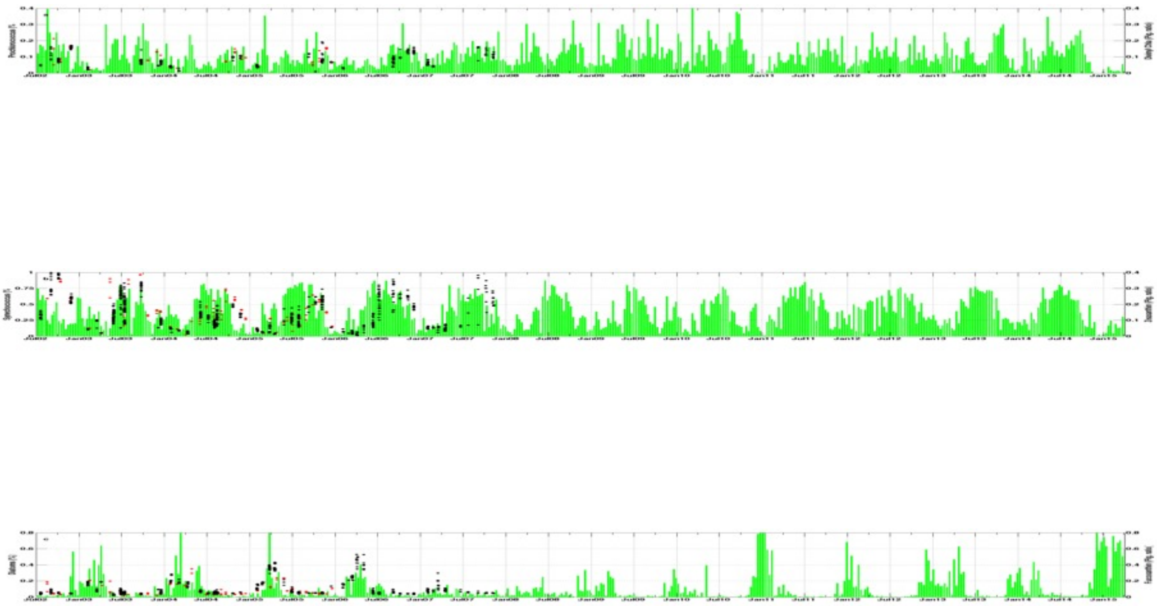

Fig. 3 *Temporal percentage (green bars, left axis) of each phytoplankton group identified by PHYSAT-Med in the Ligurian Sea. Red and black dots (right axis) represent respectively the HPLC pigments ratio.*

4. Conclusions/Discussion

PHYSAT-Med provides us a regionalized algorithm to estimate dominant phytoplankton groups (nanoeukaryotes, Prochlorococcus, Synechococcus, diatoms, coccolithoprorids and Phaeocystis-like) in the first optical depth of the Mediterranean Sea. The comparison exercise performed here using in situ HPLC datasets and previous measurements shows a reasonable agreement for four groups, Prochlorococcus, Synechococcus, nanoeukaryotes and diatoms. Our study evidences the dominance of Synechococcus over prochlorophytes throughout the year, whereas nanoeukaryotes were more abundant during winter months. However, diatoms seemed to augment during the spring period (March to April), especially in the Ligurian and Adriatic seas. It is clear that data analysis through PHYSAT-Med provides hints only on the most abundant phytoplankton types and in the surface layer but it could be still considered a useful tool for monitoring the dynamics and maintenance of phytoplankton biodiversity in the Mediterranean. Also, PHYSAT-Med could potentially be also used as a tool for Marine Strategy Framework Directive at basin scale.

5. Acknowledgements

This research was supported by the PERSEUS European Project and CTM2014-58181-R Spanish National Project. We thank to Severine Alvain and members of LOG (UMR 8187) for their contribution to this study. The authors acknowledge the NASA/GSFC/DAAC for providing access to L3 MODIS products. In situ HPLC dataset was obtained from SESAME EU Project, BOUSSOLE Project and MAREDAT data.

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Towards sustainability for Atlantic Bluefin tuna in the Mediterranean Sea: Perseus research findings

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Abstract

Tuna are key top predators that play an important role in marine food webs. They are also a valuable economic resource that is heavily fished, raising concerns about the long-term sustainability of the tuna stocks. PERSEUS research has concluded that long-term sustainability of tuna stocks can only be achieved by integrating knowledge acquired from various disciplines and stakeholders in order to better understand, respond, and adapt to changes affecting the marine environment and its resources. This communication summarizes the findings of the research and provides specific insights for science-based policymaking for the management and conservation of the bluefin tuna.
Keywords: Bluefin tuna, ecology, assessment,

1. Introduction, Material and Methods, Results

The role of oceanographic information

Tuna migrate to the Mediterranean, as it provides favorable environmental conditions for them to spawn and for their offspring to grow and survive. Models that depict the relationship between Atlantic bluefin tuna spawning ecology and environmental variability show that bluefin tuna is an "environmentally-driven spawner" since it is highly dependent on regional oceanographic conditions: salinity; current velocity; and water temperature, which account for about half of the explained variance in spatial distribution of larvae (Fig. 1).

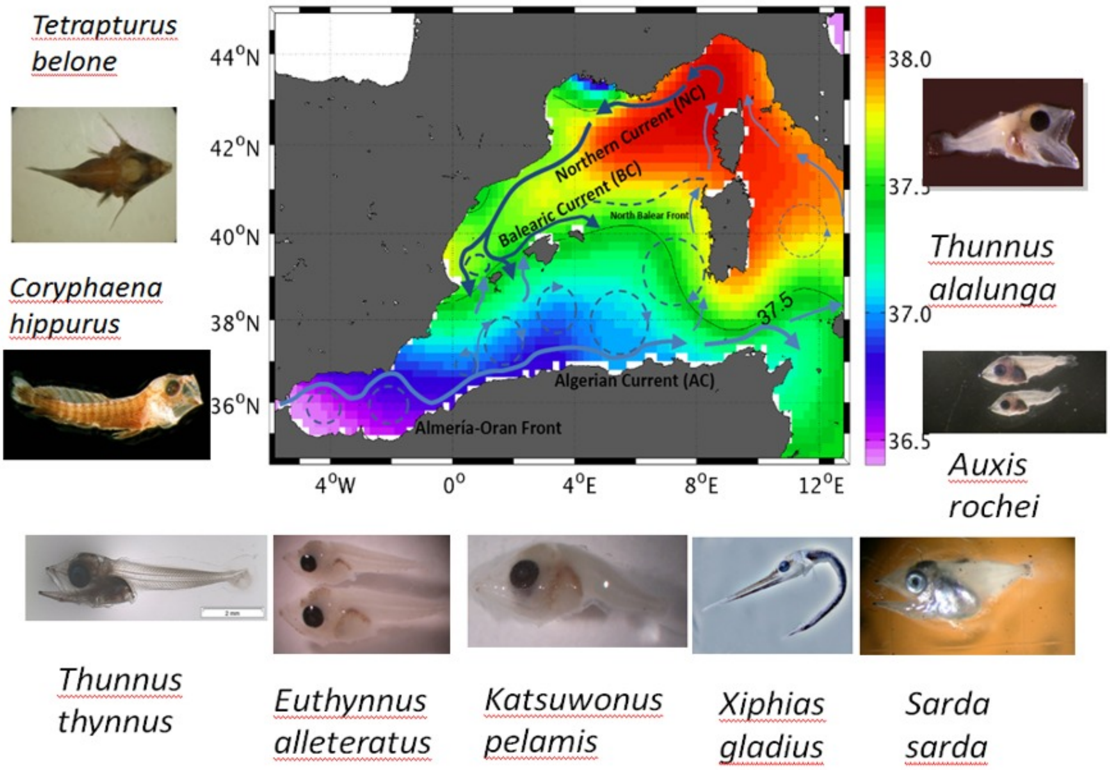

Fig.1 *Oceanography of the western Mediterranean. The Balearic Sea (NW Mediterranean) is the main study area. It is a high dynamic area where less saline recent Atlantic water (blue colours in map) that enters through the Gibraltar channel merges with the high saline resident Atlantic water (red colours in map) forming a salinity front (green colours). Different species of large pelagic fish aggregate in this area to spawn*.

Biological and hydrological data from annual surveys show that oceanographic conditions play a large role in where bluefin tuna choose to spawn. Spawning grounds are related to the position of the salinity front when water temperatures reach a minimum threshold required. Thus reproduction takes place depending on the prevailing oceanographic conditions (WP4; Fig. 2).

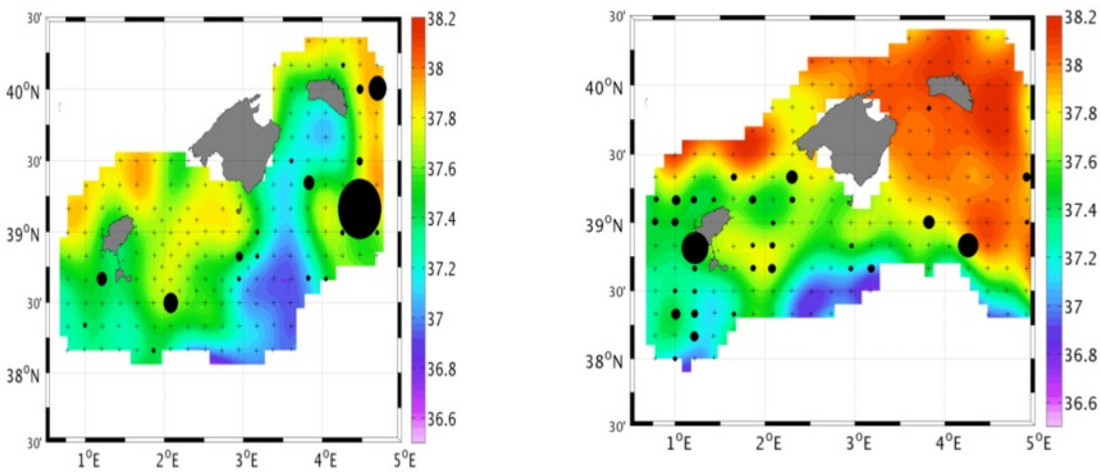

Fig. 2. *Spawning distribution areas in two different oceanographic scenarios.The green colours approximately locate the salinity front. Black dots indicate larval densities, star signals sampling stations and colours indicate salinity.*

Traditional methods of assessing tuna abundance do not take into account environmental dependency. However, Atlantic bluefin tuna larval abundance data has proven to be a useful index of spawning stock abundance. This fishery-independent index of abundance for bluefin tuna has been recently improved by incorporating larval habitat models. Marine protected areas can reduce bycatch of top pelagic predators including Atlantic bluefin tuna, but up until now it has been unclear how to best identify key locations for protection. PERSEUS has identified key oceanographic factors that are common for other tuna species worldwide: salinity, current velocity, water temperature. These variables can be measured and should be considered when determining areas of critical habitats that could become marine protected areas for tuna.

Decision support tools
Policy-makers now have access to various decision support tools based on real-time and long-term time series data (WP3 in Perseus, eg. Figure 3). Technologies such as remote sensing and drifting buoys fitted with data-loggers allow us to explore and understand how the ecology of Atlantic bluefin tuna is linked to oceanographic variability, and can help us to predict and map bluefin tuna spawning areas and larval distribution. These new oceanography products are designed based on the knowledge of how environmental variability drives the ecological processes, and can provide an excellent support tool for assessing abundance of bluefin tuna and for management and conservation of the species (e.g. Hobday et al. 2010).

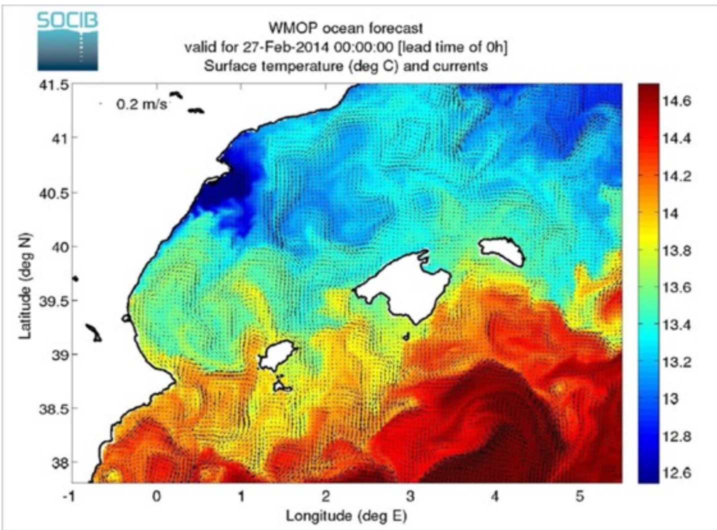

Fig. 3 *Ocean forecasting model (WMOP) providing data on surface temperature (ºC) and currents (http://www.socib.es/?seccion=modelling)*

4. Conclusions/Discussion

Long-term sustainability of marine resources

Scientists, stakeholders and decision-makers across all sectors need to consider how long-term environmental changes may affect the diversity and distribution of apex predators. The measures that may ensure sustainability for bluefin tuna today may not be the measures that we may need in the future, since nature and humans evolve and so do the requirements for sustainability. We therefore encourage the widespread participation of scientists, decision-makers, fishermen and society to enlarge our global vision of sustainability.

Within the context of the Bluefin tuna conservation, a workshop was organised to assess the potential of the Adaptive Marine Policy (AMP) Toolbox (PERSEUS WP6, Garmendia et al., submitted) to support the development of adaptive policies. The potential contribution of the bluefin case study (i.e. spawning habitat models) to support the design of dynamic pelagic marine protected areas was analysed throughout a step-by-step use of the web version of the AMP Toolbox. Main activities included the identification of potential stakeholders and relevant information (e.g. research projects, management measures, legal documents, and science-based tools) to design, implement and monitor dynamic protected areas. Several key elements to consider in dynamic ocean management of the Bluefin tuna were identified: 1) multi-stakeholder engagement from both EU and non-EU countries, including fisheries managers, scientists and the fishing industry; 2) importance of the legal framework at national and international levels; 3) spawning habitat models have a potential role to improve the management of bluefin while taking into account environmental variability; and 4) a long-term strategy to support adaptive management tools like AMP is needed.

As a concluding remark, this work provides a real example of a science-policy approach to support the management of Bluefin tuna by integrating ocean observing systems, ecological models and adaptive management policy frameworks.

5. Acknowledgements

This communication is the results of collaborative work by the Insituto Español de Oceanografía (IEO), the Balearic Islands Coastal Observing and Forecasting System (SOCIB), the College of Oceanic and Atmospheric sciences (University of Oregon, USA) and NOAA (USA). Besides funding from Perseus, this work was funded by Spanish national funded projects (Bluefin, BALEARES, 2009-07944 MAR and ATAME, 2011-29525-004-02). Researchers and technicians involved in this study, and workshop participants, are warmly thanked.

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Response of the Black Sea's benthos ecological functions to an environmental gradient

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Abstract

The management of the GES of the benthos in a changing environment and the definition of management strategies that preserve GES require tools able to predict the modifications of environmental conditions and to link these modifications to the status of the benthic system. Here we combine statistical and mathematical modelling in order to make that link using a large data set collected over the north-western shelf. A trait-based approach is used to assess the functional composition of the macrobenthos by associating the considered species to a list of biological, ecological and behavioral traits. A regionalization of the seafloor is proposed based on the significant trait-environment relationships.

Keywords: Traits, habitat mapping, anthropogenic impact, statistical and mathematical modelling

1. Introduction

For decades the Black Sea, and in particular its north-western shelf, has been exposed to multiple stressors like eutrophication, deoxygenation, pollution and overfishing that have affected the health and functioning of its ecosystem. The fact that climate change and acidification may superimpose to these stressors aggravates the situation, and strongly complicates the understanding and prediction of the response of living communities to perturbations, due to the non-linear combination of climatic and non-climatic stressors whose resulting net effect may not be additive but, instead, may either be greater (synergistic effects) or smaller (antagonistic effects) than anticipated (Folt et al. 1999). Also, the differentiation of the environmental impact of each single stressor on the ecosystem which is necessary for the spatial planning of human activities in marine areas in space and time (in relation to Marine Spatial Planning) in view of achieving or sustaining the Good Environmental Status (GES) requires the development of adequate advanced methodologies.

Because they integrate the interactions with the atmosphere, the continents and the sediment and because they take the non-linearity of ocean processes into account, ocean numerical models are good candidates for mapping physical and environmental conditions and to understand and differentiate the impact of various stressors (eutrophication, climate change) on this mapping. However, the assessment of several descriptors of GES and in particular of the potential changes in biodiversity poses a perennial problem to ocean modellers and requires the development of specific approaches in order to connect the predictions of ocean models on the environment with descriptors of GES and biodiversity.

Here we propose use statistical tools in order to make the link between the wealth of information on the environment provided by an ocean model of the Black Sea with the functions of the benthic (north-western shelf) ecosystem and indicators of biodiversity. We choose benthos because through the wide diversity of functions it supports (e.g. biomass production, grazing, recycling, bioturbation, filtering, redistribution of food resources, waste decomposition), it is considered as an important ecosystem component for sustaining the delivery of goods and services to humans (e.g. climate regulation, cultural service, to support fisheries through the provision of food or habitat). We opt for a functional description of the macrobenthos using a trait-based approach. It means that the biodiversity of a community will be described by the diversity of the traits of its species (i.e. morphological, physiological, behavioural or phenological feature measurable at the individual level that can ultimately be linked to their performance, Violle et al., 2007).

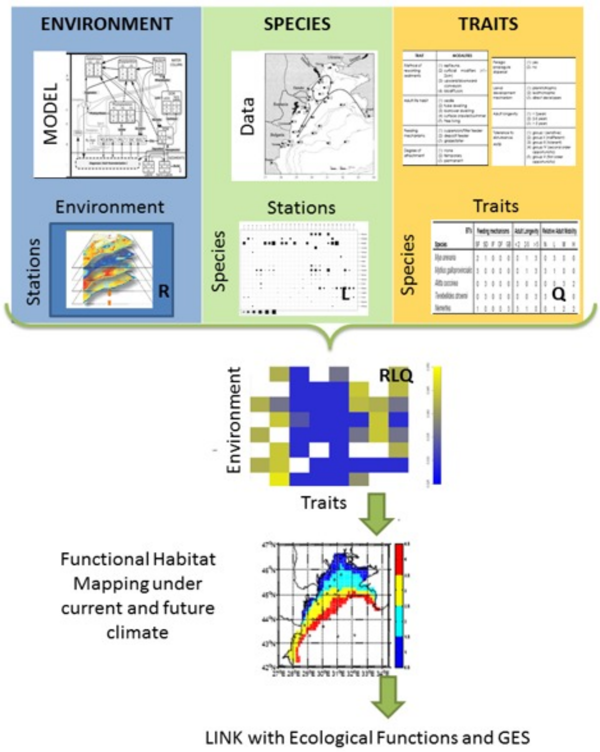

Fig. 1: *Schematic representation of the approach developed in this study. RLQ is the environment*traits matrix and refers to a statistical method described in section "Materials and methods".*

Statistical methods are used in order to determine the environmental conditions that significantly explain the distribution of the macrobenthos traits. Then, we propose a regionalization of the Black Sea bottom based on the functional composition of its macrofauna and we assess how this mapping may evolve under scenarios of environmental changes. The strategy is illustrated in Fig. 1. The final aim is to support environmental policy makers and managers in the definition of management strategies that would preserve the GES of the benthos as well as of the associated goods and services considering the multiple stressors acting on the systems.

2. Materials and methods

We use the data set collected in August 1995 over the Black Sea north-western shelf during an expedition conducted in the frame of the EU EROS 21 project (Wijsman et al., 1999). Each dominant species is described by a list of 13 biological and behavioural traits (i.e. reproduction technique, propagule dispersal, larval development mechanism, feeding groups, feeding mechanisms, maximum adult size, longevity, degree of attachment, relative adult mobility, adult movement method, propensity to move through the sedimentary matrix, method of reworking sediments, ecological groups as classified by Grall and Gle´marec; 1997, Gle´marec and Hily, 1981)). The environmental conditions are provided by field data and extended with the results of a three-dimensional ocean model run for the same period (Capet et al., 2013). This allows considering a wide list of environmental conditions characterizing the sediment (e.g. median grain size, silt content, organic carbon, total nitrogen, iron, phosphorus, manganese, C/N ratio of organic matter) and bottom water (e.g. water depth, mean/range over the year/summer of temperature, salinity, shear stress, oxygen). All this information is gathered in three tables: species distribution (presence/absence) across stations (L), environmental characteristics of the stations (R) and the species affinities for trait modalities (Q) (see Fig. 1). The determination of the trait-environment relationships requires the simultaneous analysis of these three tables. We follow the procedure described in details in Dray et al., (2014) that combines a 3-table ordination technique (RLQ method) and the fourth-corner approach. The significant trait-environment relationships identified by the RLQ analysis are used to propose a regionalization of the Black Sea bottom based on the characteristics of the functional habitat (using Self-Organizing Map procedure as described in Allen and Sommerfeld, 2009).

3. Results

The analysis shows that the adult longevity, relative adult mobility and the degree of attachment are the traits that are the most linked with environmental variables and in particular they are all correlated with depth, with the range of oxygen and salinity and with the mean value of temperature and shear stress. The trait associated to the bioturbation potential is significantly linked to all the selected environmental variables except depth while the feeding mechanisms are linked to environmental variables that are proxies of the amount of organic matter in the sediment (e.g; range of bottom oxygen and salinity and sediment labile organic carbon content, total phosphorus in the sediment) but not with the shear stress. Environmental variables significantly correlated with the traits are then used to propose a regionalization of the Black Sea north-western shelf sea floor. Several regionalization patterns produced by a Self-Organizing Map procedure on the basis of those environmental variables have been produced using various number of regions. A division of the shelf in 4 sub-regions (Fig. 2) has been selected, which provides significant correlations between each trait and region numbers. In particular, Region 1 corresponds to an area receiving high river inputs from the Danube, Dnepr and Dnestr and submitted to a high variability of environmental conditions. Species found in Region 1 belong to the family of Nereidae (Nereis diversicolor, Nereis succinea, Nereis zonata, Nereis rava) or to the phylum Nemertea (Nemertini varia). They are considered as tolerant species (AMBI sensu), have a short life span, are mainly omnivorous and feed through grazing/biting and/or deposit feeding (but not filter feeding). They have a high mobility above (crawler/swimmer) and in the sediment (biodiffusers that have free 3D movements via burrow system). In this region macrobenthos is more limited by the availability of oxygen rather than by the organic matter supply. Seaward, we have species with a low or no mobility, which are (temporary or mostly permanently) attached to the substrate and are suspension feeders and/or deposit feeders. These species are either long living bivalves with surface bioturbators (activities restricted <1- 2 cm sediment) (Modiolula phaseolina), or the sessile epifauna characterized by no mobility and permanently attached (Mytilus galloprovincialis, Molgula euprocta) or belong to the sedentary polychaetes that live in a fixed tube with a low or no mobility (Polydora ciliate, Lagis koreni, Melina palmata, Terebellides stroemii) which can be both suspension feeders or deposit feeders.

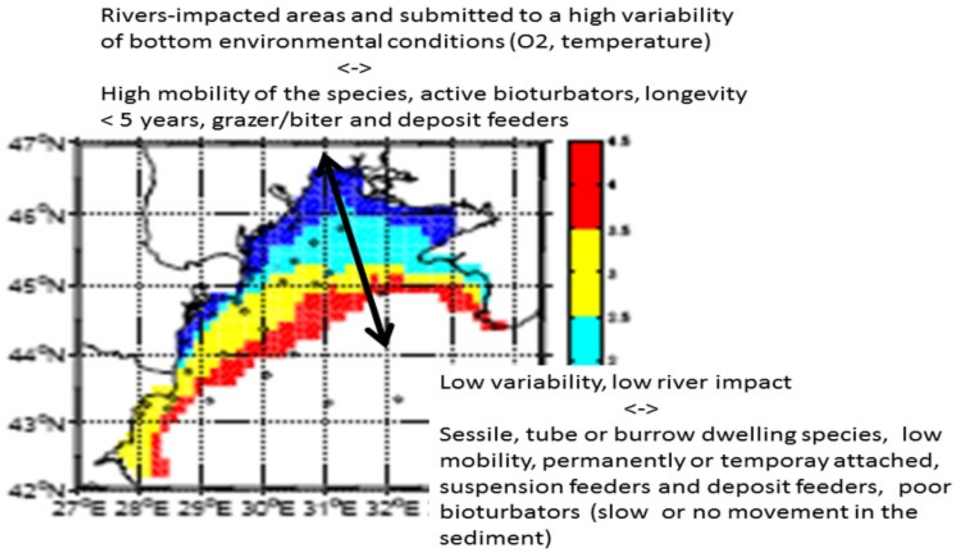

Fig. 2: *Regionalization of the Black Sea north-western shelf bottom produced by the ocean model based on the similarities of environmental variables that are significantly correlated with the traits of the macrobenthos. Number of the scales refers to the region numbering.*

4. Conclusions

We propose a trait-based approach in order to link the information on the environment provided by in-situ data and ocean models with the ecological functions, life history, physiology, behaviour and sensitivity characteristics of the benthos. We use the fourth-corner method in order to identify significant trait-environment relationships and to graphically display them. We investigate whether the identified significant trait-environment relationships may reflect known ecological processes. A regionalization of the Black Sea bottom is then proposed based on a mapping issued from the ocean models of areas with similar environmental characteristics. The environmental conditions selected for this mapping are those that have been found significantly correlated with the traits. This mapping differentiates regions submitted to a high natural variability and river discharges and regions located more offshore. The next step will be to connect the ecological functions associated with the traits of the macrobenthos to a valuation of the goods and services it provides to humans.

5. Acknowledgements

This study was funded within the scope of the PERSEUS (FP7, EC grant n°287600) project.

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Preliminary model assessment of basic marine ecosystem properties of the Northern Adriatic Sea.

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Abstract
The Northern Adriatic Sea ecosystem dynamics is simulated using the BFM-NEMO fully coupled modelling system. Hindcast simulations allowed the assessment of basic ecosystem attributes (vigor, organization), underlying the ecosystem health and the "Good Ecosystem State" (GES) as defined by the EU-MSFD Directive. Emphasis is posed on the primary production (vig or) and Phytoplankton population functional type structure organisation). The simulated data are compared with analogous data originating from advanced remote sensing techniques.
Keywords: Biogeochemical modeling, vigor, organization

1. Introduction

Ecosystem health (Costanza and Mageau, 1999) can be described by basic ecosystem properties: among them "vigor" and "organization". The "vigor" of a system is simply a measure of its productivity. The organization of a system refers to the number and diversity of interactions between the components of the system. Here we seek an assessment of the basic marine ecosystem "vigor": that is to say the planktonic primary production. Similarly, we assess the basic ecosystem organisation by analysing the phytoplankton population structure at the functional type level. Such basic properties are assessed via numerical simulations carried out with a fully coupled physical-biogeochemical model and compared with corresponding advanced remotely sensed observations.

2. Materials and methods

The used modelling system is based on the on-line coupling of the general circulation model NEMO (Nucleus for European Modelling of the Ocean; Madec, 2008, http://www.nemo-ocean.eu, version 3.4) with the lower trophic level biogeochemical Model BFM (Biogeochemical Flux Model, Vichi et al. 2015, http://bfm-community.eu). The system is implemented in the Northern Adriatic Sea with a horizontal resolution of 800 m and 48 vertical z-levels. Surface forcing data were provided from ECHAM5 regional climate simulations (Scoccimarro et al., 2011). Initial conditions and open boundary data and open boundary data, have been obtained from Mediterranean Sea circulation NEMO based simulations (Lovato et al., 2013), forced with the same atmospheric data used here. Open boundary conditions followed Oddo et al. (2008). The land based river runoff and nutrient load data adopted considers 16 major Adriatic Rivers (Ludwig et al., 2010). Open boundary and initial conditions for BFM state variables were taken from BFM-POM (Princeton Ocean Model-Biogeochemical flux Model) Adriatic Sea simulations. The full NEMO-BFM coupling simulations span the period 1996-2010; here we show the results for the period 1998-2007 that is covered by available remote sensing data.

3. Results

The 1998-2007 annually averaged spatial distribution of the simulated vertically integrated gross primary production (gC $m^{-2}d^{-1}$) across the Northern Adriatic Sea is shown in Fig.1a, and it

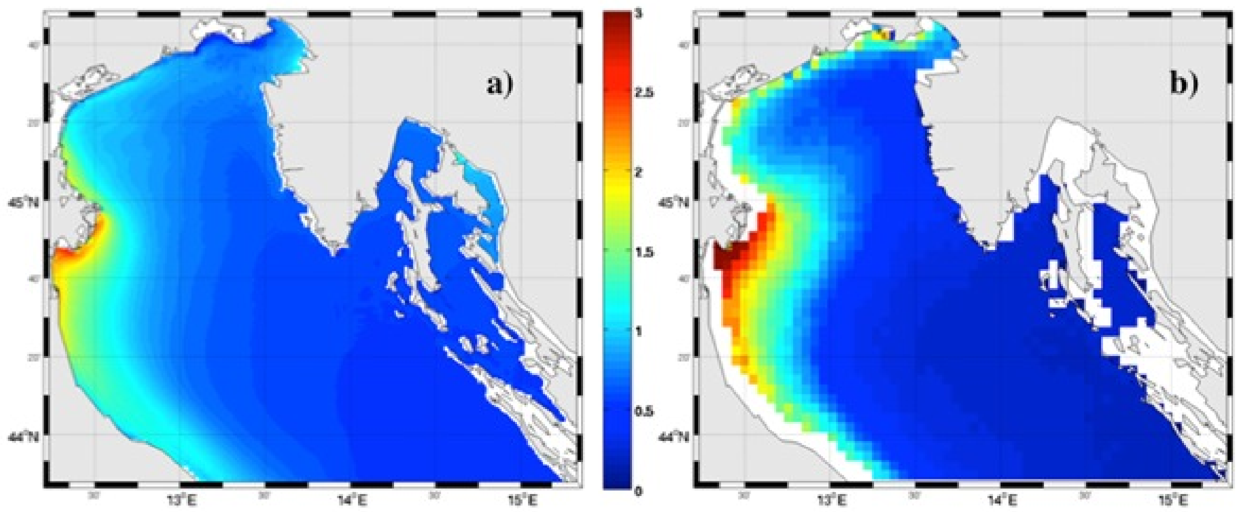

Fig.1 *Annual average for a) simulated gross primary production (gC $m^{-2}d^{-1}$) and b) estimated primary production (gC $m^{-2}d^{-1}$) from satellite data (SeaWifs, Marullo et al., 2013) for the period 1998-2007.*

is compared with corresponding average from SeaWiFS observation (Marullo et al., 2013) (Fig. 1b). The satellite map shows that the most productive areas, are the coastal areas most directly affected by river discharge, notably the Po delta area. Productivity decreases rapidly with a coastal to offshore west-east gradient. Thus pattern is replicated by the numerical simulation.

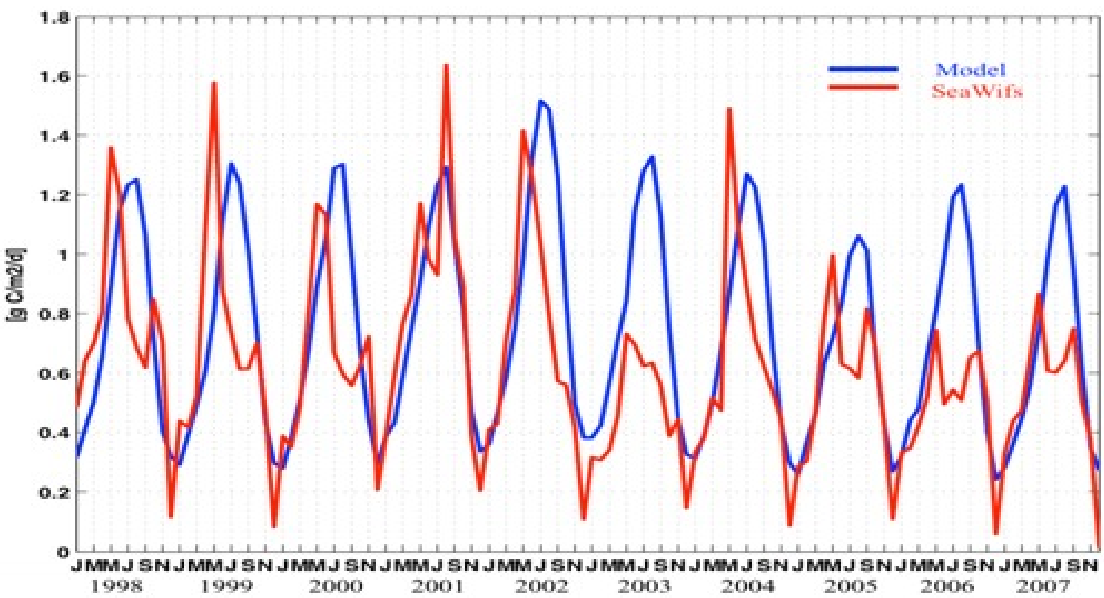

Fig.2 *Time series of gross primary production (g $Cm^{-2}d^{-1}$) from the model and estimated primary production (g $Cm^{-2}d^{-1}$) from satellite data (Marullo et al., 2013) for the period 1998-2007.*

The overall distribution of the model based productivity is in good qualitative agreement with the observation, however with a degree of underestimation in the coastal areas and a slight overestimation in the offshore regions. The 1998-2007 time series of the simulated primary productivity is plotted against the corresponding SeaWiFS observations (Marullo et al., 2013) in Fig.2. The productivity seasonal cycle described from the satellite observations is characterised by a winter to summer progressive increase, sometimes with a double peak characteristics. The model grossly captures such pattern, with an overall agreement in magnitude (although with a temporal shift in the timing of the peak) for the period 1998-2004. Subsequent years shows a remotely observed seasonal cycle characterised by a double peak, a pattern that apparently the model is not able to capture.

Despite such discrepancies the annually averaged SeaWiFS value (0.64 g $Cm^{-2}d^{-1}$) and the corresponding simulated value (0.76 g $Cm^{-2}d^{-1}$) are in agreement. To assess the "organisation" property we compared the remotely observed phytoplankton size based structure with the corresponding model functional types biomasses. The model resolves 4 different groups (diatoms, autotrophic nanoflagellates, picophytoplankton and large phytoplankton). Comparison with satellite data we considered three sizes based functional types defined, namely, picophytoplankton, nanophytoplankton and microphytoplankton. The diatoms and large phytoplankton belong to the microphytoplankton groups. The consistencies of the observed groups is given as percent with respect to the total chlorophyll_a concentration measured by SeaWiFS or computed by the model. Figs. 3 show the maps of the 1998-2007 annually averaged simulated spatial distribution of microphytoplankton (Fig. 3a), nanophytoplankton (Fig. 3c) and picophytoplankton (Fig. 3e) and the corresponding observation (Figs. 3b,d,f). The maps show (in agreement with observations) that the West-East trophic gradient is mostly due to microphytoplankton. The simulated nanophytoplankton distribution is "specular" to the microphytoplankton distribution; a pattern that is observed also in the remote data but the model provides a clear overestimation of the nanophytoplankton type. Picophytoplankton. (Figs. 3e,f) distribution indicate clearly that the model underestimate such functional type.

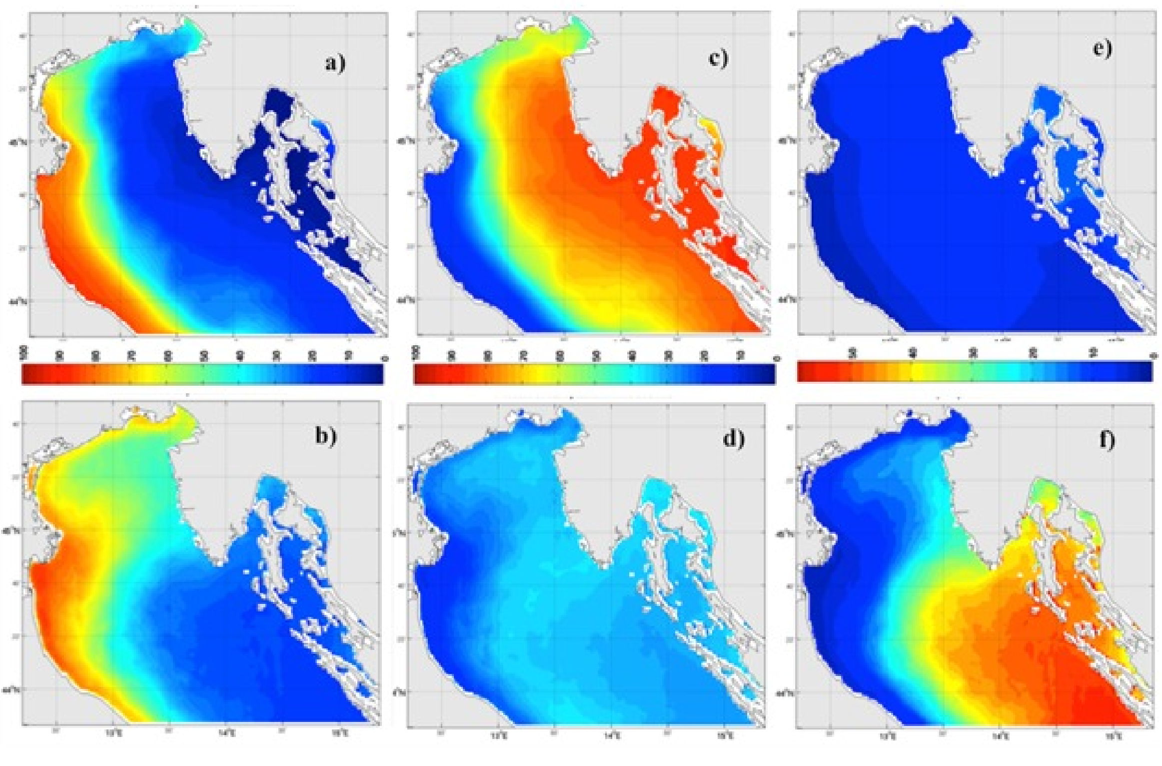

Fig.3 *Annual average in terms of percentage for a) microphytoplankton, b) nanophytoplankton and e) picophytoplankton. b), d), f) and corresponding estimated primary producers from satellite data (SeaWifs, Marullo et al., 2013) for the period 1998-2007.*

The above considerations about the functional type consistencies are confirmed by the 1998-2007 time series of the simulated and observed data three functional groups (Fig. 4) are plotted against corresponding remotely sensed observations from SeaWifs (Marullo et al., 2013).

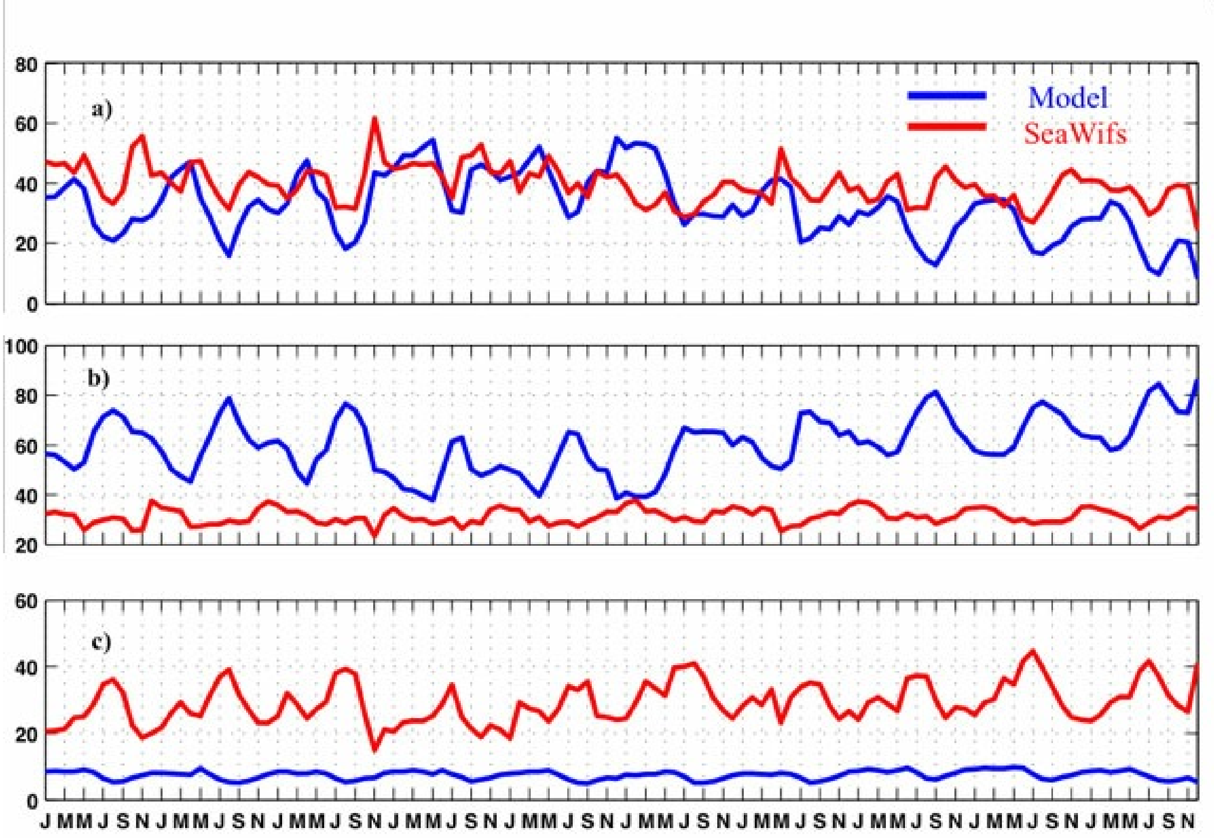

Fig.4 *Time series of monthly mean percent for a) microphytoplankton, b) nanophytoplankton, c) picophytoplankton from the model and estimated from satellite data (Marullo et al., 2013) for the period 1998-2007.*

4. Conclusions/Discussion

This preliminary work shows for the first time an assessment of basic ecosystem properties based on numerical simulations and validated against advanced remotely sensed observations of basic ecosystem properties underlying the "health" of the marine ecosystem. The outcome of such effort indicated that potentially the numerical model might have skill in providing information about the marine ecosystem "health". However, differences can be clearly observed mostly in the replication of the productivity seasonal cycle rather than in the overall spatial distribution. More complicated is the "organisation" definition, since the current state of the BFM-NEMO parameterisation indicates a not negligible difference with respect to the information provided by the satellite. Particularly the underestimation of the picophytoplankton call for a better parameterisation of the biogeochemical (nutrient uptake and picophytoplankton completion for nutrient against bacteria) and ecological processes (picophytoplankton grazing from (heterotrophic flagellates) underlying the representation of the microbial loop dynamics.

5. Acknowledgements

This research was supported by the EU-FP7 PERSEUS project, (Grant Agreement No. 287600). The authors acknowledge the use of the BFM system (http://bfm-community.eu/).

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Scenarios of ecosystem health from End-to-End models of the Mediterranean Sea and Black Sea

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Abstract

High (food web) and low trophic level (hydrodynamic/biogeochemical) models are coupled to represent whole ecosystem dynamics for key areas of the Mediterranean (Gulf of Lions, Adriatic, Northern Aegean) and Black sea (east and west). We used integrated models, calibrated for period 2000-2010, for climatic and fisheries scenarios (2010-2020) and compared several indicators measuring ecosystem health components (vigor, resilience and organization) computed for reference and future scenarios. Results are showing context dependent dynamics emerging from complex integrated models, and give indication of direction of change of GES indicators that suggest appropriate management actions to maintain ecosystem health.
Keywords: coupled models, ecosystem assessment, climatic and fisheries changes, Good environmental status.

1. Introduction

The European Marine Strategy Framework Directive (MSFD) (EU, June 2008) requires that by 2020 a good environmental status (GES) will be reached in all of the European seas, by using indicators for 11 qualitative descriptors. Although there is consensus on the need for defining references and GES, the definition of indicators and their comprehensive integration for a complete assessment of marine ecosystem status is not easy. We used End-to-End models to integrate hydrodynamic/biogeochemical features of marine systems, i.e. low trophic level processes (LTL in the following), with dynamics of invertebrates, fish and their fisheries, i.e. high trophic level (HTL). Integrated tools provides dynamic assessment of ecosystem health under climatic and fishing scenarios using a set of indicators estimated on results from calibrated end-to-end models.

2. Materials and methods

The analysis is made by linking hydrodynamic, biogeochemical and food web models for some key seas of the Mediterranean Sea, such as Gulf of Lions, Adriatic Sea and Aegean Sea and for two areas of the Black Sea. Model results are used to assess the status of marine ecosystem in terms of ecosystem health components: vigor, organization and resilience (Costanza and Mageau, 1999). Existing models were firstly updated and standardized to a common structure (34 and 29 functional groups for the Mediterranean and Black Sea models, respectively). Second, we coupled HTL model to the hydrodynamic-biogeochemical ones following the procedure used in Libralato and Solidoro (2009). The procedure is based on i) extension of HTL model to cover main variables of LTL one, ii) adjustment of extended End-to-End model to represent at best LTL variables. For the Mediterranean we used the OPATM-BFM (Lazzari et al., 2012) forced with physical outputs produced by the CMCC-MFS16CM Ocean General Circulation model. The simulation carried out spans the period 2000-2020 with a spin-up phase of 5 years. For the Black Sea a calibrate LTL model was used (Capet et al., 2013). Climate scenarios (2011-2020) were performed using nutrient river discharge scenarios and data from PERSEUS Deliverable 4.6 (i.e., BAU, BA, MFA, REB, RBE, see Table 1). Fisheries scenarios included 10% increase and decrease of effort by gear (all, demersal trawlers) and of fishing mortality for some key groups (small pelagics and large pelagics).

Table 1. *Synthetic description of Climate and Fisheries scenarios applied to the future conditions (2011-2020): changes described with respect to last year of the hindcast (2010).*

Climate scenarios (applied for period 2010-2020)	
BAU	Business as usual: high per capita food consumption; high agricultural productivity as in 2010; no change in efficiency of fertilizers
REB	Regional expanding Block: high per capita food consumption; agricultural productivity as in 2010; rapid increase of N and P in fertilizers
MFA	Market For All: low per capita food consumption; low agricultural productivity; slow increase of N and P in fertilizers in some countries, no change for others
REB	Regional Blue Economy: high per capita food consumption, low meat; medium-high agricultural productivity than in 2010; moderate increase in fertilizers in counties with surplus
BA	Blue Archipelago: low per capita food consumption, low meat; medium agricultural productivity; moderate increase of use of fertilizers
Fisheries scenarios (applied to BAU 2010-2020)	
P10All	Increase by 10% the fishing effort for all the fleets
M10All	Decrease by 10% the fishing effort for all the fleets
P10Btwl	Increase by 10% the fishing effort for the benthic trawls
M10Btwl	Decrease by 10% the fishing effort for the benthic trawls
P10SPF	Increase by 10% the fishing mortality for sardine and anchovy
M10SPF	Decrease by 10% the fishing mortality sardine and anchovy
P10LPF	Increase by 10% the fishing mortality for large pelagic fish species
M10LPF	Decrease by 10% the fishing mortality for large pelagic fish species

Following Costanza and Mageau (1999) ecosystem health was evaluated by calculating over time a set of indicators used to compare the "*health*" in terms of i) *vigor* (NPP , net primary production; T, Throughput; Catch, total catch), ii) *organization* (K's Q , Kempton's Q biodiversity index; FiB, Fishing in Balance; AMI, Average Mutual Information; A, Ascendency; FCI, Finn's Cycling Index; mPL, Mean Path length) and iii) *resilience* (H-AMI, =Entropy – AMI = (Capacity-Ascencency) / Throughput); SfG, Scope for Growth = Total production – Total primary production) plus a couple of other indicators were also analysed: catch over biomass (C/B) report and trophic level of catch (TLc).
Calibration of the dynamic End-to-End model was performed on the 2000-2010 LTL and HTL data (Fig. 1, left panels), but when local data (fishing effort and biomass estimate) were available before 2000 for HTL groups the longer time series were used to improve model accuracy using climatology estimated for the hindcast (2000-2010) for the LTL groups. Climate and fisheries scenarios were compared other than for their main variables (flows and biomasses) also looking at dynamics over time of the large set of indicators (Fig. 1; right panels).

3. Results

Results from the End-to-End models of the BAU scenario for the period 2011-2020 were compared to those of the reference period fitted to data (Reference, 2000-2010), while all other climatic and fisheries scenarios were compared with BAU 2011-2020 (Table 2). Results for the Mediterranean and the Black Sea show that changes from Reference to BAU were in general greater than changes between climatic future scenarios.

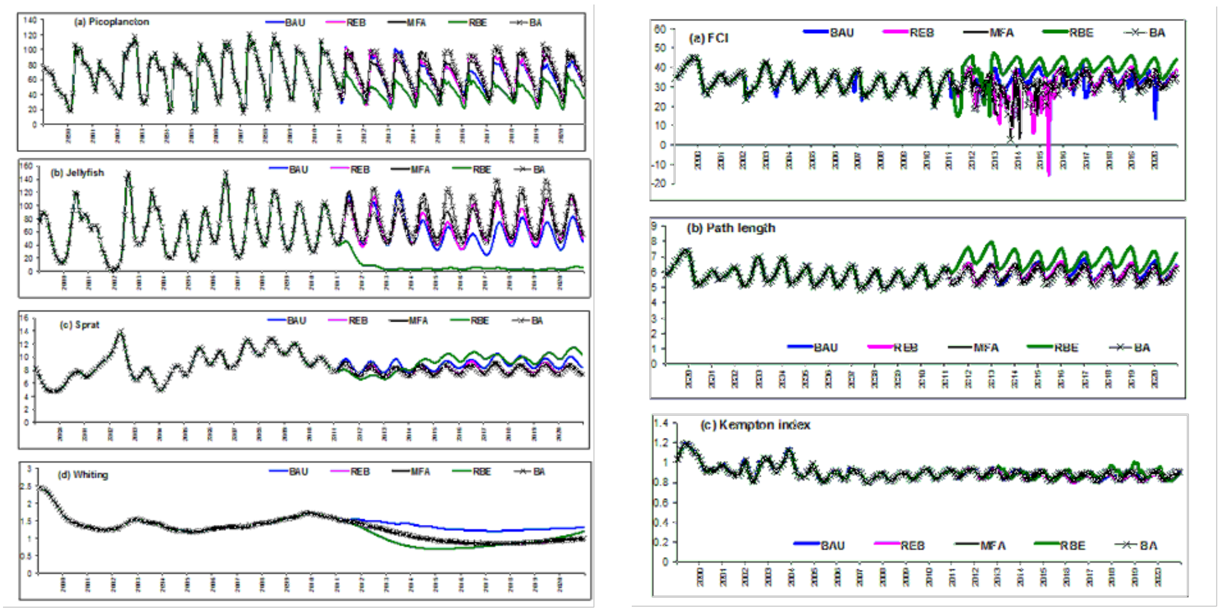

Fig.1 *Dynamic of End-to-End model for hindcast (2000-2010) and future (2010-2020) for the Eastern Black Sea. Left and right panels present some state variables and ecosystem indicators, respectively.*

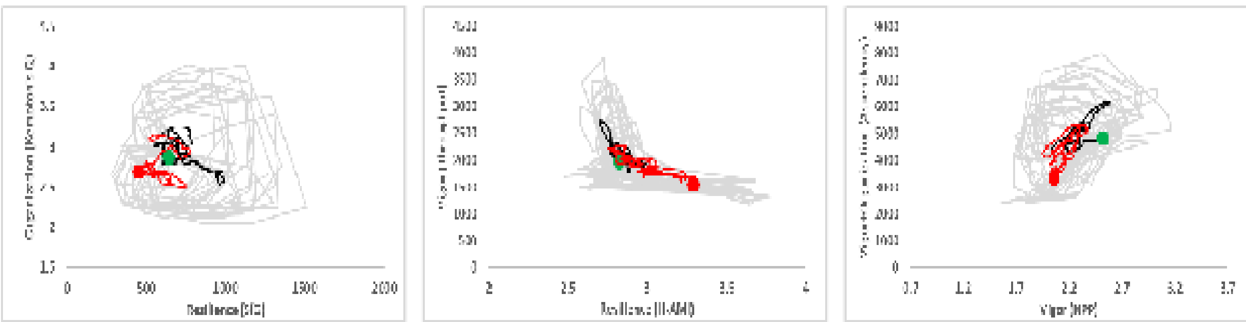

Fig.2 *Dynamics of components of ecosystem heath (vigor, resilience and organization) over time for the Adriatic system. Initial conditions (2000, green dot) and hindcast period (2000-2010, black line) are distinguished from BAU dynamics (2010-2020; red line) and final situation (red dot; 2020). Values are 12 order moving averages of monthly results (grey line).*

Table 2. *Summary of results in terms of indicators of ecosystem health (columns) for climatic and fisheries scenarios applied to Mediterranean key areas (rows). In bold are reported the average values for REF and BAU scenario; other values are percent change. Positive (blue) and negative (red) relevant changes are highlighted (light color = changes >2%; darker color = changes >5%).*

		Vigor			Organisation						Resilience		Exploitation	
		NPP	T	Catch	K's Q	FiB	AMI	A	FCI	mPL	H-AMI	SfG	C/B	TLc
Gulf of Lion	***Ref (2000-2010)***	***1.02***	***2620.06***	***0.54***	***1.05***	***-3.E-04***	***2.21***	***5795.52***	***-150.11***	***10.27***	***3.18***	***765.88***	***1.E-03***	***3.60***
	BAU (2010-2020)	***1.06***	***2688.98***	***0.58***	***1.04***	***-6.E-04***	***2.21***	***5952.10***	***-287.50***	***9.91***	***3.18***	***794.75***	***1.E-03***	***4.04***
	(BAU-Ref)/Ref	4.2	2.6	6.7	-0.9	91.7	0.1	2.7	91.5	-3.6	-0.1	3.8	1.9	12.2
	climatic scenarios													
	(BA-BAU)/BAU	-0.22	-0.10	-0.04	0.02	0.93	-0.01	-0.10	337.01	0.18	0.01	-0.14	0.06	0.07
	(MFA-BAU)/BAU	-0.12	0.52	0.47	0.04	-0.58	-0.01	0.52	65.75	-0.47	-0.08	0.77	-0.13	0.10
	(REB-BAU)/BAU	-0.23	0.00	0.01	0.01	0.28	-0.01	-0.01	201.92	0.01	-0.01	0.01	0.02	0.06
	(RBE-BAU)/BAU	-0.35	-0.24	-0.24	0.00	1.16	-0.01	-0.26	52.76	0.30	0.01	-0.35	0.08	0.05
	fisheries scenarios													
	(P10AII-BAU)/BAU	-0.02	-0.11	5.17	-0.90	-31.18	0.02	-0.10	322.33	0.17	0.01	-0.14	5.25	-0.83
	(M10AII-BAU)/BAU	0.02	0.13	-5.39	0.99	24.15	-0.02	0.11	-73.81	-0.21	-0.02	0.17	-5.47	0.88
	(P10Btwl-BAU)/BAU	-0.02	-0.11	5.17	-0.90	-31.18	0.02	-0.10	322.33	0.17	0.01	-0.14	5.25	-0.83
	(M10Btwl-BAU)/BAU	0.02	0.13	-3.94	-0.46	14.81	-0.01	0.12	383.47	-0.23	-0.02	0.16	-4.00	0.72
	(P10SPF-BAU)/BAU	0.00	-0.02	4.36	0.06	-26.25	-0.01	-0.03	65.83	0.00	0.01	-0.04	4.41	-0.46
	(M10SPF-BAU)/BAU	0.00	0.02	-4.38	-0.06	22.41	0.01	0.03	30.62	0.00	-0.01	0.03	-4.43	0.51
	(P10LPF-BAU)/BAU	0.00	0.00	0.01	0.00	0.21	0.00	0.00	47.31	-0.01	0.00	0.00	0.01	0.01
	(M10LPF-BAU)/BAU	0.00	0.00	-0.03	0.00	-0.21	0.00	0.00	83.55	0.01	0.00	0.00	-0.03	-0.01
Adriatic Sea	***Ref (2000-2010)***	***2.31***	***2148.21***	***1.20***	***2.95***	***1.E-02***	***2.41***	***5090.04***	***34.02***	***152.95***	***2.82***	***718.98***	***2.E-03***	***3.45***
	BAU (2010-2020)	***2.13***	***1850.68***	***1.01***	***2.74***	***9.E-03***	***2.32***	***4287.64***	***40.85***	***17.30***	***3.02***	***582.09***	***2.E-03***	***3.45***
	(BAU-Ref)/Ref	-7.6	-13.9	-15.7	-7.1	-23.2	-3.7	-15.8	20.1	-88.7	7.2	-19.0	-8.6	-0.1
	climatic scenarios													
	(BA-BAU)/BAU	0.09	0.76	0.27	-0.02	0.73	0.78	1.39	-1.39	-188.14	-0.74	1.11	-0.30	-0.02
	(MFA-BAU)/BAU	0.30	1.21	0.45	-0.05	1.21	0.84	1.85	-5.16	261.71	-0.84	1.79	-0.50	-0.02
	(REB-BAU)/BAU	0.11	0.73	0.24	0.00	0.71	0.67	1.26	0.40	-164.23	-0.64	1.07	-0.31	-0.02
	(RBE-BAU)/BAU	0.31	1.34	0.51	-0.07	1.40	0.74	1.90	-5.40	-70.11	-0.79	1.97	-0.55	-0.03
	fisheries scenarios													
	(P10AII-BAU)/BAU	0.02	0.01	2.62	-1.61	4.80	0.04	0.04	0.77	-103.13	-0.05	0.01	2.64	-0.10
	(M10AII-BAU)/BAU	-0.02	-0.01	-2.78	1.73	-4.60	0.03	0.02	-159.17	-259.48	0.00	-0.02	-2.79	0.08
	(P10Btwl-BAU)/BAU	16.49	27.95	4.42	0.04	3.40	1.88	28.45	-27.08	-1500.99	-9.09	41.30	-16.11	-3.15
	(M10Btwl-BAU)/BAU	-0.02	26.77	-12.69	1.73	-28.61	2.09	27.54	-32.96	-300.60	-8.91	39.57	-23.09	-2.32
	(P10SPF-BAU)/BAU	0.00	-0.40	0.56	-0.31	1.87	-0.12	-0.49	0.01	-115.52	0.21	-0.60	0.82	0.12
	(M10SPF-BAU)/BAU	0.33	0.43	-0.74	0.59	-2.33	0.41	0.77	-12.29	29637.78	-0.45	0.65	-1.02	-0.14
	(P10LPF-BAU)/BAU	0.00	0.00	0.11	0.02	-0.02	0.00	0.00	-0.07	-40.95	0.00	0.00	0.12	0.07
	(M10LPF-BAU)/BAU	0.00	0.00	-0.12	-0.02	0.02	0.00	0.00	0.67	66.66	0.00	0.00	-0.12	-0.07
Northern Aegean Sea	***Ref (2000-2010)***	***1.38***	***1616.60***	***0.67***	***6.78***	***-3.E-05***	***1.98***	***3190.16***	***36.78***	***7.86***	***2.65***	***461.37***	***4.E-03***	***3.84***
	BAU (2010-2020)	***1.34***	***1542.40***	***0.63***	***6.46***	***-1.E-04***	***1.98***	***3042.62***	***44.90***	***8.24***	***2.66***	***429.40***	***4.E-03***	***3.83***
	(BAU-Ref)/Ref	-2.6	-4.6	-5.5	-4.8	329.7	0.0	-4.6	22.1	4.8	0.0	-6.9	0.5	-0.2
	climatic scenarios													
	(BA-BAU)/BAU	0.13	-0.07	1.88	4.96	13.36	0.22	0.27	5.07	-2.09	0.40	-0.05	-2.17	0.11
	(MFA-BAU)/BAU	-5.09	-7.23	-11.85	-5.83	133.22	-0.08	-7.17	-12.94	5.48	-0.58	-11.50	-0.79	-0.48
	(REB-BAU)/BAU	-5.09	-7.10	-11.73	-5.77	131.72	-0.08	-7.05	-6.75	5.24	-0.58	-11.30	-0.79	-0.46
	(RBE-BAU)/BAU	-5.10	-7.03	-11.64	-5.64	130.86	-0.08	-6.97	-14.08	5.11	-0.58	-11.17	-0.79	-0.45
	fisheries scenarios													
	(P10AII-BAU)/BAU	-0.02	-0.03	6.88	0.28	-106.24	-0.01	-0.04	-8.75	-0.12	-0.03	-0.07	7.18	-0.16
	(M10AII-BAU)/BAU	0.02	0.03	-7.22	-0.83	94.32	0.04	0.07	4.43	0.13	0.01	0.07	-7.51	0.17
	(P10Btwl-BAU)/BAU	0.00	0.00	1.69	-0.18	-20.80	-0.01	-0.01	1.40	-0.03	0.00	-0.01	1.76	-0.07
	(M10Btwl-BAU)/BAU	0.00	0.00	-1.72	0.16	20.35	0.01	0.01	3.82	0.03	0.00	0.01	-1.78	0.07
	(P10SPF-BAU)/BAU	-0.01	-0.02	2.80	-0.36	-60.61	-0.03	-0.05	4.61	-0.08	0.00	-0.04	2.99	0.00
	(M10SPF-BAU)/BAU	0.02	0.02	-2.95	0.37	54.82	0.03	0.04	4.80	0.09	0.01	0.05	-3.14	0.00
	(P10LPF-BAU)/BAU	0.00	0.00	0.04	0.62	-0.67	0.00	0.00	4.87	-0.03	0.00	0.00	0.07	0.00
	(M10LPF-BAU)/BAU	0.00	0.00	-0.07	-0.72	0.85	0.00	-0.01	1.78	0.03	0.00	0.00	-0.11	-0.01

Results show important context dependence responses: although some changes related to fisheries effect are similar, effects of climatic changes on indicators are quite different from system to system (Table 2), thus suggesting that local conditions (both in terms of fishing pressure and nutrient discharge) both at initial status (reference) and for the future are relevant for local assessments of ecosystem health. Table 2 shows also that some indicators like FCI and FiB, are in general more sensitive to changes than others (e.g. TLc).

4. Conclusions/Discussion

The offline integration procedure (Libralato and Solidoro, 2009) permits adjustments that make the End-to-End approach closer to the two ways coupling (e.g. Akoglu et al., 2015), keeping the analysis capabilities of EwE and enabling representation of integrated ecosystem changes. Integrated method showed to be successful for Mediterranean (Gulf of Lion, Aegean, Adriatic) and Black Sea (eastern and western) systems. Results indicate that differences between future climatic scenarios are smaller than between reference/hindcast and future conditions. Future conditions are going to worsen the ecosystem health conditions in most of the systems with current exploitation levels, while are worsening if fishing pressure increase.

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What are marine ecosystem services worth? The V-MESSES database

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Abstract

The economic valuation of marine ecosystem services is considered as a rather challenging issue directly related with the implementation of the MSFD. To this context, an in-depth review of marine valuation studies was conducted within the framework of the PERSEUS project and the obtained information was integrated into a spatially explicit valuation database, namely V-MESSES, in order to provide the necessary monetary values in the Southern European Seas for the conduction of cost-benefit analyses. The V-MESSES database contains to date 93 studies providing over 110 value estimates for numerous marine ecosystem services enabling the valuation of four categories and 20 subcategories of marine ecosystem services.
Keywords: Mediterranean and Black Sea; Marine ecosystem services; Economic values; Valuation databases.

1.Introduction

Nowadays, it is generally acknowledged that marine ecosystems contribute essentially to the human welfare providing numerous ecosystem services (Beaumont et al., 2007; Kildow and McIlgorm, 2010). Although the markets have the capability to trade only a few marine ecosystem services at prices taking into consideration their real value to the society, for the majority of the marine ecosystem services the prices do not reflect generally their total economic value according to their characteristics. The main reason of this distortion is that no accurate and reliable value estimates of marine ecosystem services are available incorporating environmental and social externalities. Moreover, the economic valuation of marine ecosystem services is associated with the requirements of the Marine Strategy Framework Directive (MSFD). Specifically, the MSFD introduces an ecosystem-based approach to the management of human activities and the design of appropriate strategies and measures in order to achieve a Good Environmental Status of European seas. This can be considerable supported by a reliable quantification of the cost of degradation and the social value of the protected marine ecosystem services. Therefore, the present work intents to contribute to the on-going research on the cost of marine degradation and the triggered benefits and costs for the improvement of the marine environment though the implementation of the MSFD. Specifically, it aims at collecting and critically reviewing the existing knowledge on the marine ecosystem values for all the Mediterranean and Black Sea countries (Southern European Seas). Furthermore, the collected and analysed information is organized in a specific valuation database, namely "*Valuation database for Marine Ecosystem Services of Southern European Sea V-MESSES*".

2. Methodological approach

The V-MESSES database has been developed within the framework of PERSEUS research project. It targets the provision of monetary values for analysts and decison makers responsible for the evaluation and the design of appropriate measures and policies for the achievement of better and most efficient governance in the Mediterranean and Black Seas. V-MESSES provides the value estimates needed for a thorough implementation of the necessary cost-benefit and cost-effectiveness analyses for the assessment of programmes of measures. It is available and searchable online at http://www.perseus-net.eu/en/database_marine_valuation/index.html.

The main aim of the database is the provision of specific information through a user friendly way facilitating the potential user (e.g. researchers, policymakers, NGOs) to seek easily and effectively for the basic and more useful points of the examined studies without requiring the access on the original studies. Moreover, the systematic and detailed record of the valuation studies can contribute to the identification of the status of the existing knowledge or the technical gaps enhancing the relevant scientific research in the corresponding field. Furthermore, the V-MESSES database has been developed in order to collect specialized information for the implemented Stated Preference valuation methods, such as the Contingent Valuation and the Choice Experiments methods. Finally, even if the V-MESSES database focuses on studies in Mediterranean and Black Seas, it is foreseen the integration of additional marine valuation studies expanding its scope and spatial scale in the future.

The V-MESSES database has been developed in an Excel based form consisting of five different information fields (Fig.1). The first field of the database is "*Entry ID*", which contains the main bibliographical characteristics of the examined studies, such as information about the authors, the title of the study, representative keywords, the source of publication including the abstract of each study separately.

The second field "*Object of valuation*" includes information relevant to the characteristics of the valued ecosystem service, such as the area of the case study (region, country or specific location), the spatial scale of the study and the physical characteristics of the asset. Moreover, information about the examined ecosystem services and types of ecosystems is provided in an hierarchical form in order to facilitate the acquisition of the necessary information at different levels of aggregation. In the third field of "*Methodological design*" information about the implemented valuation approaches is presented including the utilised valuation method, the examined valuation measure and payment vehicle, the use of visual material etc. The "*Data collection*" field contains information about the data collection process focusing mainly on the implementation of stated preference valuation studies incorporating information, such as the population surveyed, details about the sampling method and the data collection procedure etc. Finally, the last field is the "*Data analysis*", which provides details about statistical modelling and analysis of data and the valuation results. Specifically, information is presented about the types of the economic values and whether the total economic value is estimated or some of its component (such as use or non-use, direct, indirect, option, existence values etc.). Moreover, the corresponding monetary estimates are reported for each study separately including technical issues, such as the implemented statistical measures, the developed bid function models, the treatment of zero/protest bidders, the potential test for biases, etc.

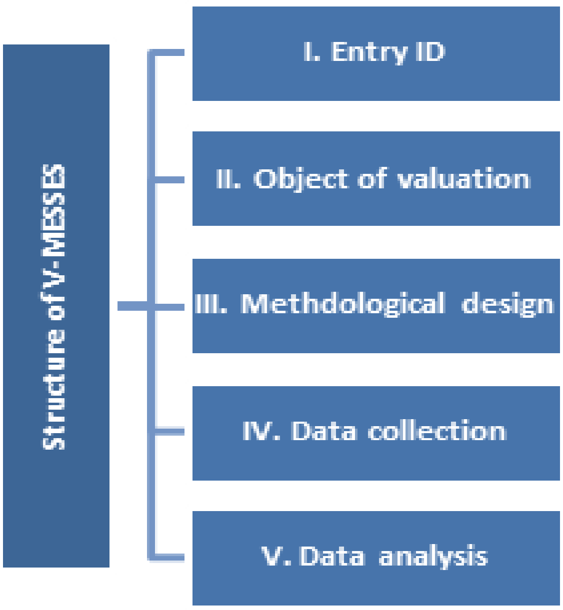

Fig.1 *V-Messes S different informations field*

The V- MESSES database was developed within the framework of a specialised web-based procedure in order to identify, select and analyse the necessary information from the peer-reviewed studies and to integrate the obtained information into the database with the most efficient and accurate way To this purpose, a multidisciplinary review team was established, which was involved in the review process, in the design of the database and in the validation of the submitted data. Furthermore, a general protocol was developed according to the CEBC (2010) so as to ensure high standards for accessing, appraising and synthesizing the scientific information.

The corresponding data were collected through an exhaustive search for peer-review sources in: (a) online databases and catalogues (such as Marine Ecosystem Services Partnership, National Ocean Economics Program, ENVALUE, GEVAD, Cost-Impact Marine Valuation Database, GecoServ, etc.), (b) organizations and professional networks and (c) the internet generally.

3. Results

Totally, the V- MESSES database includes compiled information from 93 peer reviewed primary valuation studies providing over 110 value estimates for 4 different categories and 20 subcategories of marine services. The outcomes of the preliminary analysis of the examined studies resulted that the studies involve a wide variety of different types of estimates. Specifically, some studies provide mean WTP values per person or per household per year or one-off payment, while other studies aggregated estimates. Moreover, some estimates are presented as gross value expressed by an economic activity and others in terms of net income. Many studies refer to marginal changes in a specific area, while others assess a broader scale of services at regional level. Finally, some estimates reflect the direct or indirect uses and others non-use or total economic values. Table 1 provides values, which have been compiled from the V-MESSES database for various coastal and marine ecosystem services.

Furthermore, it should be highlighted that the selection and implementation of economic values cannot be considered as a simple task as several conditions should be fulfilled in order to result in effective and efficient value transfers. Additional complexity is added by the high uncertainty, which can be attributed to various parameters, such as the imperfect knowledge of ecological and economic relationships in the marine environment (UNEP-WCMC 2011). Therefore, we suggest the use of expected values and the conduction of specific sensitivity and probabilistic analyses in order to increase the robustness of reliable value transfers.

Table 1.*Estimated values (in €2012) for coastal and marine ecosystem services.*

	Estimates	Minimum value	Maximum value	Single value	Monetary units
Provisioning services					
Provision of food	2	4.9	14		€/ha
Raw materials	1			0.3	€/ha
Provision of genetic resources/medicine	1			22	€/ha
Regulating services					
Gas and climate regulation	3	10.8	1,425		€/ha
	1			3.5 – 4.9	€/person
Erosion control	2	2.5	175		€/ha
Bioremediation of waste	3	3.7	14,680		€/ha
Water purification and	2	20	1,400		€/ha
detoxification	1			116.8	€/household
	1	4.9	10.7		€/person
Cultural services					
Recreation and leisure	1			19.2	€/ha
	24	1	133		€/person
Aesthetics and inspiration	1			40,260	€/ha
	1	0.5	1.8		€/person
Cultural heritage and identity	1	0.5	4.2		€/person
Spiritual and religious values	1			647	€/ha
Science and education	1	1.0	4.9		€/person
Supporting services					
Primary production	2	0.5	496		€/ha
Biogeochemical cycling	1			28,500	€/ha
Ecosystem stability and	1			54	€/ha
resilience	3	22.8	184.8		€/person
Habitats	1			545	€/ha
Biodiversity	1			0.5	€/ha
	28	2.3	152.4		€/person

4. Conclusions

The V-MESSES database was developed to facilitate the access to the relevant literature allowing the stakeholders to conduct valuation studies within the context of the MSFD easily and effectively. Moreover, the V-MESSES database will help analysts and decision makers to take into consideration the cost of degradation and the triggered benefits and cost components in the benefit-cost analysis of the examined projects and policies. Nevertheless, the selection of the appropriate values is not a simple task requiring specific level of knowledge. Concluding, the usefulness of the V-MESSES database within the framework of the MSFD depends on factors such as the broader acceptance of environmental valuation, the quality and policy relevance of new studies, and the development of standards for performing benefits transfer of marine services valuation.

5. Acknowledgements

This work was funded by the European Union 7th FP for research, technological development and demonstration under Grant Agreement No. 287600 PERSEUS project (www.perseus-net.eu).

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Socioeconomic analysis of pressures of the coastal areas and open seas in the Mediterranean and the Black Sea

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Abstract

The first regional integrated socioeconomic analysis conducted in the Mediterranean and Black Seas of human activities as drivers exerting pressures on marine and coastal ecosystems was carried out under the PERSEUS project. This assessment is required by the Marine Strategy Framework Directive and other ecosystem-based policy approaches, to prepare measures to achieve Good Environmental Status of these seas. Built on existing data, it highlights the knowledge gaps. Six main maritime sectors have been assessed: fisheries and aquaculture, maritime transport, coastal tourism, oil and gas extraction, cables and pipelines and finally desalination. The fishing sector is presented as illustration.

Keywords: MSFD, social, economic, assessment, drivers

1. Introduction

The ecosystem-based approach to management, as prescribed in the Marine Strategy Framework Directive (MSFD) recognises the need to consider economic and social aspects in interaction with environmental concerns. This paper presents the results of the economic and social analysis conducted within PERSEUS of the human activities which exert pressures on marine coastal ecosystems of the Mediterranean Sea and the Black Sea and subregions: Western Mediterranean Sea, Central Mediterranean Sea, East Mediterranean Sea and Black Sea. In addition, the analysis here distinguishes between activities taking place in coastal areas and those in open waters (beyond 200m depth), representing a first attempt at an analysis of this kind.

The economic and social analysis is essential to characterise drivers of change on the marine environment and ultimately to manage them and the pressures and impacts that stem from their activities. In this regard, the development of policies as prescribed within the MSFD, as well other ecosystem-based policy approaches promoted by the two Regional Sea Conventions, requires that policy makers obtain knowledge about the activities which they seek to manage, and how policies may affect these activities. Within the PERSEUS project, the economic and social analysis provides a first step in preparing and developing adaptive policies and scenarios (in WP6) for the project’s pilot areas.

The methodology follows that given through MSFD guidance documents to Member States. The focus of the analysis is on the main marine sectors such as fisheries, aquaculture, port operations, maritime transport, recreational activities and coastal tourism, underwater pipelines and cables, and oil and gas extraction as well as desalination.

2. Materials and methods

Based on the methodology recommendations formulated by the MSFD Working Group for Economic and Social Analysis (WG ESA, 2010), the marine water accounts approach was considered as the most appropriate for the present analysis. This provides a pragmatic approach and sufficient level of detail to produce a comprehensive assessment to characterise human activities which create pressures and impacts on the marine environment. The approach may be implemented using available data. Data on marine water uses and economic sectors were gathered from European databases such as Eurostat that provides a consistent amount of economic information related to relevant sectors in the European marine regions; and the European Environment Agency which disseminates mostly physical data. Other sources of data have been mostly: national statistical authorities, EU sectoral analysis, trade associations, regional (GFCM) and international organizations (e.g. FAO FishStat, Sea Around Us).To be in line with the large ecosystem categories, a distribution of the marine activities was attempted between coastal areas and open sea.

3. Results

The present analysis of the use of waters has been performed for the abovementioned sectors through social and economic indicators such as production parameters, production value or Gross revenue, Gross Value Added (GVA) (when possible) and employment in order to describe as far as possible the socioeconomic importance of these activities, and to assess their environmental pressures and impacts on ecosystems. In the present paper, the fishing sector is presented as an illustration as it constitutes a crucial sector causing generally the most damage in the Mediterranean and the Black Sea. Results for the other activities can be consulted in the corresponding PERSEUS deliverable (Sauzade et al, 2013).

Mediterranean fisheries are dominated by small-scale fisheries, as 82% of the registered vessels in the Mediterranean are less than 12 meters long and therefore have a limited range and more appropriate for coastal fishing (Collet, 2011). Most fisheries in the Mediterranean and Black Sea are coastal fisheries operating in less than 200 meters depth.

The analysis of the fishing sector has been conducted through the selection of socio-economic indicators for the four sub-regions identified (Western Mediterranean, East Mediterranean, Central Mediterranean and Black Sea). The sector analysis at sub regional scale takes into consideration the landings in weight, number of vessels, employment, gross revenues and Gross Value Added. Various sources of data have been used, such as FAO FishStat for the landings, EU and UN statistics for the economic data and employment as well as sectoral studies. Socio economic data are generally provided at national level, which makes difficult to analyse sub regional activities for countries presenting maritime facades on several seas (as Spain, France, Morocco…) or sub regions (Turkey, Italy…). Some missing data have been reconstructed, especially for non EU countries and some countries figures have been allocated to the main sub-region in order to avoid hazardous segregations. Most recent available data have been used, which may correspond to different periods. Official fisheries statistics have been taken into account , while often subject to caution, notably due to the difficulty to record informal operations taking place all along the coasts such as day to day landings; and for political reasons in order to avoid too strict application of constraining fisheries management plans, such as subsidies reduction decided at national, European or regional levels to limit overfishing. Nevertheless, this analysis provides an overall view of the relative socioeconomic importance per sub region which is illustrated in Fig 1.

Large differences in the shares are shown between the different sub regions. Landings reflect partly the productivity of the area, which is large for the Black Sea, compared to the more oligotrophic Mediterranean sub regions. Number of vessels and employment are function of the share between EU and non EU countries in each sub regions, non EU countries being generally characterized by large fleet and high subsistence employment although most of the fleet of EU countries are now small and efficient, requiring professional employment, thanks to past management plans aiming to reduce overfishing. Compared to landings, gross revenues show evidence of higher prices per unit, due to a larger proportion of high economic value catches.

Difficulties were also met to assess fishing activities specific to open waters, beyond 200m depth. This segregation is meaningful from an ecological perspective but not considered in the current socioeconomic statistics. However, a first approach was possible regarding the landings (2%-4% of the total weight), by selecting in the FishStat database some fish species generally caught in open waters.

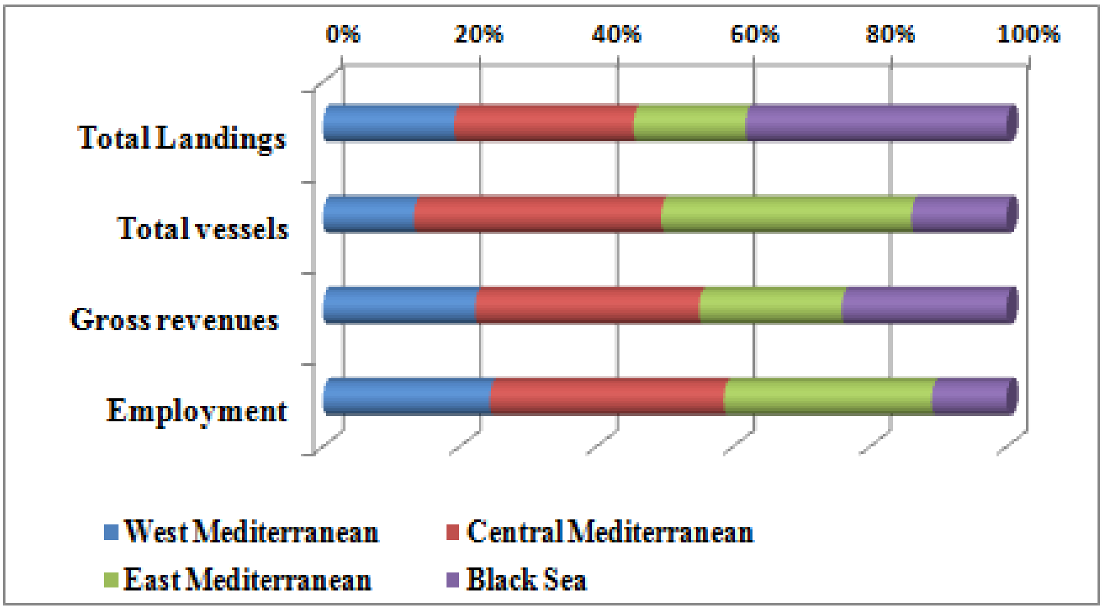

Fig. 1: *Overview of economic and social indicators for the fishing sector*

As for all the analysed sectors, the study includes a characterization of the activity according to the main environmental impacts following the MSFD descriptors. Intensive fishing and overfishing is a major environmental pressure causing losses of biodiversity, valuable marine resources and ecosystem services (Worm, 2006; World Bank and FAO, 2008) but can also reduce the spawning biomass of a fishery below optimal levels such as sustainable maximum yields, which may lower the capacity of marine food webs to occur at a normal abundance and diversity (FAO, 2012). The effects of fishing on habitats are related to the physical disturbance by bottom gears in contact with the seafloor. These include removal of large physical features, reduction in structural biota and in complexity of habitat structure. Fisheries impact may be direct, such as impacts on marine populations or habitats from unselective gear, destruction of the seabed or interactions with rare or endangered species. Additionally, fishing activities may cause stress, impact, trophic chain perturbations and by-catch of marine mammals (Herr, 2009) but also causes impacts due to marine litter (Ten Brink et al., 2009).

4. Conclusions/Discussion

The regional economic and social assessment of the uses of Mediterranean and Black Sea waters at basin scale is an innovative approach that has never been conducted to date. The assessment also represents a real challenge to collect relevant data adapted to the scale of the study area. Further to the constraints observed on the data, developing and harmonizing common data classifications and approaches at national and regional scale including collaboration with national statistics authorities are strongly recommended to perform such socioeconomic assessments in the future.

5. Acknowledgements

This work is part of the research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, http://www.perseus-net.eu Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow". This paper was prepared in the basis of the work done within this project, by the contributors of the tasks T1.2 and T2.2, Analysis of pressures in socioeconomic terms: Sauzade, D. (Plan Bleu) Kontogianni, A. Skourtos M. and Damigos, D. (AEGEAN) Shivarov, A. (BSNN) Pascual, M. Ojea, E. and Markandya, A. (BC3) Boteler, B. and Grünig, M. (Ecologic Institute) Freeman S. (Haifa U.) Jiménez, J. Valdemoro, H. and Ariza, E. (UPC-LIM) Puig, M. Darbra and Casal, J. (UPC-CERTEC).

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Inventory and critical assessment of marine policy in the Southern European Seas

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Abstract

This paper provides an inventory and critical assessment of legal and institutional marine policy in the Southern European Seas (SES), the Mediterranean Sea and Black Sea. Conducted in 2012, the methodology for compiling the inventory consisted of a review of academic literature, websites, legal policy documents and expert opinions. Together with the inventory, a policy assessment was carried out based on multiple levels of governance, including specific countries, regional seas, and multilateral and international governance of marine areas. The results present the marine governance framework in the SES as a complex web of laws, regulations, strategies, plans, and institutions.

Keywords: Adaptive policy, Mediterranean Sea, Black Sea, MSFD, multilevel governance, ecosystem-based approach

1. Introduction

This conference paper presents an inventory of policies and institutions in the Mediterranean and Black Sea, which was compiled in 2012 in the process of developing an Adaptive Policy Framework (APF) and toolbox intended to assist policy-makers in better managing the human-induced pressures on the marine environment.

The overarching EU-wide policy guiding the management of the marine environment is the Integrated Maritime Policy (IMP) (EC, 2007), which seeks to establish an integrated approach to the management and governance of oceans, seas and coasts to strengthen sustainable economic and environmental development. The Marine Strategy Framework Directive (MSFD) constitutes the environmental pillar of the IMP and aims to reduce pressures on the marine environment brought about by human activities. It provides a clear regulatory framework requiring that environmental targets are met in an effort to obtain ‘good environmental status’ (GES) based on eleven qualitative descriptors (EC, 2008): 1) biological diversity; 2) non-indigenous species; 3) commercially exploited fish and shellfish; 4) marine food webs; 5) human-induced eutrophication; 6) sea-floor integrity; 7) alteration of hydrographical conditions; 8) concentrations of contaminants; 9) contaminants in fish and other seafood; 10) marine litter; 11) introduction of energy, including underwater noise (EC, 2008).

A guiding principle of the MSFD is ecosystem-based management, an integrated approach to resource management that considers the entire ecosystem. At the same time, the MSFD recognises that the dynamic nature of marine ecosystems and their natural variability in combination with the intensification of human use patterns and anthropogenic pressures means that the achievement of GES will invariable need to be flexible and adapted over time (EC, 2008).

This review focuses on governance frameworks and measures which take an ecosystem-based approach to management as a guiding principle promoted by EU policy. It is also based on identifying links that existing marine governance (i.e. institutions and policies) shares with the MSFD, focusing on the eleven GES descriptors. In addition, because the MSFD requires flexible measures to achieve

GES, key elements of adaptive policies are also identified and critically assessed. The definition of adaptive policies in this assessment follows Swanson and Bhadwal, (2009), according to whom 'Adaptive policies are designed to function more effectively under complex, dynamic and uncertain conditions. Adaptive policies anticipate the array of conditions that lie ahead through robust up-front design using (1) integrated and forward looking analysis; (2) multi-stakeholder deliberation and (3) by monitoring key performance indicators to trigger automatic policy adjustments.' Because it is impossible to anticipate all changes in policy, however, this also requires the development of an adaptive system which includes '(1) enabling the self organisation and social-networking capacity of communities; (2) decentralising governance to the lowest and most effective jurisdictional level; (3) promoting variation in policy responses and (4) formal policy review and continuous learning.' The inventory takes stock of marine policies on international and European level and then zooms in on the national governance frameworks in eight case countries, including Spain, France, Italy, Croatia, Slovenia, Greece, Romania and Bulgaria.

2. Methodology

The methodology used in this research is based on a review of academic literature and journals, institutional websites, legal, policy documents, relevant research projects (e.g. FP7) and includes expert opinions. Templates (i.e. questionnaires) were developed to guide the inventory compilation and then tailored toward regional or national governance levels, based on an initial literature review. The templates focused on key questions in regard to governance structures, links with the MSFD through GES descriptors and the ecosystem-based approach, as well as elements of adaptive policies. The templates were completed by a number of expert researchers based on topic, country and language expertise, allowing for harmonised results and a comprehensive assessment. In addition, the review and analysis was conducted by a multidisciplinary expert group to guarantee that the links and interactions between anthropogenic pressures, environmental processes and states, and economic uses of resources are properly considered. The inventory provided two main outputs: 1) a report which includes inter alia the inventory and critical assessment and 2) an accompanying database.

3. Results and conclusions

The marine governance framework in the Mediterranean Sea and Black Sea, including international and national governance of marine areas, is devised of a complex web of laws, regulations, strategies, plans, institutions and agencies. Figure 1 below shows the multiple levels of governance in the SES, as a simplified concept. The figure also shows that while there is a hierarchy of governance (i.e. international to national), this is dependent on different factors. For example, EU governance (e.g. the MSFD), is only relevant to EU Member States, which may in addition ratify or become member to international or regional conventions.

The analysis showed that, in 2012, some adaptive policy elements existed within the international framework and in EU-level policies for marine governance. These included stakeholder consultation, scientific advice and monitoring. Although these elements existed, most of the policies did not qualify as adaptive by design, but rather due to the necessity to take new scientific knowledge and changes in the environment into account in their implementation. In other words, these elements supported the monitoring, evaluation and ultimately the update of these policies within the prescribed policy time frames, as opposed to being adaptive within their design. Adaptive policy elements identified in the Black Sea region include the precautionary principle, anticipatory action, preventative action, and public participation and transparency.

Throughout the SES, national governments use a framework of governance based on *inter alia* national priorities, geographic considerations and environmental conditions to manage their marine territories.

Fig.1 *Multiple levels of maritime governance in the Southern European Seas. Source: Ecologic Institute*

The PERSEUS Black Sea pilot region covers the EU Member States Romania and Bulgaria. Looking first at Romania, in 2012, the country had taken steps to address pressures to the marine environment. Links to MSFD descriptors were identified, however a national marine strategy, in line with the MSFD was not yet developed. Moreover, marine actions tended to focus more on the regional Black Sea Environment Programme than EU policy. The conservation of biological diversity (descriptor 1) was strongly emphasized through the national implementation of the CBD.

Bulgaria, like Romania, had also placed a strong focus on international and regional conventions. In 2012, MSFD initial assessment obligations were not fulfilled (however, this has changed). Nevertheless, several measures that address MSFD descriptors were identified. Most emphasis was put on the conservation of biological diversity (descriptor 1) and contaminants (descriptor 8) having an impact on the quality of the marine waters. Key adaptive policy elements found in Bulgaria in 2012 include stakeholder and public consultation. In Romania, adaptive policy elements found include the precautionary principle, monitoring systems, and stakeholder and public consultation.

In the Aegean Sea pilot area, international and EU policy to tackle marine environmental issues is important to Greece. Greece had completed the initial assessment of the MSFD and transposed it into national law in 2012, however, several MSFD descriptors were not addressed by Greek policy or institutions. Identified descriptors included non-indigenous species (descriptor 2), human-induced eutrophication (descriptor 5), sea-floor integrity (descriptor 6), alteration of hydrographical conditions (descriptor 7), marine litter (descriptor 10) introduction of energy, including underwater noise (descriptor 11). Adaptive policy elements (stakeholder involvement and scientific monitoring) were also part of Greek marine governance strategy.

The Northern Adriatic Sea pilot region includes Italy, Croatia and Slovenia. In 2012, Italy had a well established framework for maritime governance following international, EU and regional strategies for marine environmental protection, while depending on bilateral agreements to solve boundary issues. Adaptive policy elements, most notably scientific monitoring and stakeholder consultation, as well as several MSFD descriptors were identified within the Italian marine governance framework. Finally, the assessment also suggested that both Slovenia and Croatia were taking measures to address pressures to its marine environment, and a number of links to MSFD descriptors were seen in the two countries.

Looking at the Balearic Sea and the Gulf of Lion pilot regions, both France and Spain had frameworks for the management of maritime spaces and environmental protection in 2012. The French maritime governance framework was at that time undergoing a process to develop and enhance its capability to address marine environmental issues. The National Coastal and Ocean Council and the 'Blue Book: national strategy for the seas and oceans' had recently been created

(Premier Ministre, 2009). These efforts suggested an increased awareness of marine environmental issues and demonstrated an effort to take an integrated view of marine waters and coasts. Spain's management of marine environmental issues in 2012 appeared to be predominantly driven by the MSFD. This means that an ecosystem based approach to management was applied throughout regional strategies for MSFD implementation. Moreover, the development of the Interministerial Commission on Marine Strategies shows that Spain was taking an integrated approach to ensure communication across marine strategies.

In conclusion, there are a complex policy framework and tools to manage human activities and the marine environment in place in the Southern European Seas. This is resulted from the widespread recognition of environmental degradation and the acknowledgement of the need to establish sustainable levels of exploitation. There are however, multiple challenges affecting the efficiency of existing maritime governance. These include a diverse community of countries and cultures with different political agendas and resources to implement, monitor and control the existing maritime legislation within both the Mediterranean Sea and Black Sea. Lack of transparency is also a significant barrier to government action, making it difficult to address insufficiencies regarding policies and institutions. Moreover, how the conflicts between economic and environmental trade-offs (e.g. balancing exploitation and use with environmental measures) are addressed may not be visible in a literature review.

To address elements of these barriers it would be necessary to conduct more research to improve knowledge and to enhance the effectiveness and efficiency of policies. However, rather than introducing new legislation, new knowledge, research and approaches should be integrated into the existing legislation in an effort to make the current governance and policy framework more flexible and adaptive to evolve as new information and knowledge is gained. Moreover increased sharing and coordination between institutions within and between countries could help to underpin and improve the effectiveness of the current framework in place.

5. Acknowledgements

This work is part of the research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, *http://www.perseus-net.eu* Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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Assessing the cost of marine degradation: A critical reading of the MSFD Initial Assessment reports

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Abstract
In the context of the EU Marine Strategy Framework Directive, Member States are required to conduct an economic and social assessment of the uses and the cost of degradation of the marine environment. Given the variety of alternative approaches, each Member-State has developed its own methodological approach. Consequently, the estimates differ significantly and are not comparable among the Member-States and, thus, they do not ensure transparency and accountability under the MSFD requirements. This paper wishes to contribute to the ongoing discussion on these issues through the analysis of the results of the Initial Assessments of four Mediterranean countries.
Keywords: MSFD; cost of degradation; economic value

1. Introduction

Economic valuation is strongly anchored within the logic of the Marine Strategy Framework Directive (MSFD) provided that it is a prerequisite for setting priorities within this framework in several aspects. For instance, Article 8.1 (c) of the MSFD requires an economic and social analysis of the use, and of the Cost of Degradation (CoD) of the marine environment. The Art 13(3) of the MSFD requires Member States to plan a programme of measures in order to achieve the MSFD targets, while ensuring that the measures are cost-effective and technically feasible by carrying out cost-benefit analyses (EC, 2010).

The Working Group on Economic and Social Assessment (WG ESA) developed a Guidance Document for supporting the development of the Initial Assessment of the MSFD (WG ESA, 2010). As regards the economic and social importance of the use of marine waters, WG ESA Guidance Document suggests two approaches, namely the Ecosystem Services approach and the Marine Water Accounts approach, while for the assessment of the CoD of the marine environment, WG ESA guidelines propose three different approaches, i.e. the Ecosystem Services approach, the Thematic approach and the Cost-based approach, which are very different from one another.
Given the variety of alternative approaches, it's not surprising that each Member-State has developed its own methodological framework towards preparing the Initial Assessment report required by MSFD. For instance, Spain estimated the CoD of the marine environment following the Cost-based approach. France organized the estimation of the CoD by themes, e.g. marine litter, eutrophication, etc., which are related to the main pressures listed in Annex III of the MSFD. The CoD was calculated by combing the loss of value of services rendered by ecosystem in the two states of the environment, i.e. GES and degraded, and the accounting costs incurred by the activity and related degradation (proven, perceived or potential) of the marine environment. As a result, the estimates differ significantly and are not comparable across the Member-States.

In order to shed light on those issues the Initial Assessment reports of four Mediterranean countries, namely Cyprus, Greece, Italy and Spain are examined and the results of the analysis are discussed, hoping that this paper will contribute to the ongoing discussion towards setting common ground rules that will ensure transparency and equity among the Member-States in the context of MSFD requirements.

2. Sources and data

As mentioned, WG ESA Guidance Document suggests alternatives approaches for estimating the economic importance of marine waters and the resulting CoD, which have a different starting point. As reported by a recent Commission Report to the Council and European Parliament (EC, 2014), most Member States have used the Water Accounts approach, which is less data demanding than the Ecosystem Services approach. Only two Member States (LV, UK) implemented the Ecosystem Services approach and another two (LT, SE) have used a mixture of these approaches. In addition, different marine uses have been considered by the Member States, mainly due to lack of data. The most commonly mentioned uses are fisheries, shipping, tourism, port operations, aquaculture, defence, marine research activities and renewable energy production (EC, 2014). According to the same report, the approaches used for estimating the CoD are even more diverse. Half of the Member States used a cost-based approach, five Member States (IE, LV, SE, SI, UK) used the Ecosystem Services approach, two Member States (BE, EE) used the Thematic approach, and two more (DE, LT) used a mixed approach. Furthermore, the methodology followed by BG was unclear (ibid.).

Cyprus and Greece adopted the Marine Water Accounts approach for the assessment of the value of their marine waters by calculating the financial benefits of the sectors/economic activities which are direct users of marine waters in the base line of 2010. The basic economic indicators used are: The Production Value, the Value Added and the Employment. These two countries followed a simplified Ecosystem Services approach in order to estimate the CoD that focuses on the impacts on the sectors which are direct users of marine waters and involves the cost accrued to these sectors due to the degradation of the marine environment based on the construction of hypothetical scenarios. Spain also adopted the Marine Water Accounts approach in its Initial Assessment. However, it followed the Cost-based approach to estimate the CoD of its territory waters, using as a proxy current costs incurred by the different actors involved in the protection of the marine environment. The same approaches were used by Italy in order to estimate the economic and social value and the CoD of the Italian marine waters, respectively.

3. Results

This section aims at providing data as regards the estimated economic value and the CoD for the countries under investigation. The analysis is based on compilations of existing data, namely the Initial Assessment reports prepared by the four Member States in the context of the Marine Strategy Framework Directive (MSFD).
As shown in Tables 1 and 2, the estimates differ significantly and are not comparable across the Member-States. This is attributed not only to the approaches followed but also due to the assumptions made and the availability of data.

Country	Area of jurisdictional waters (sq.km)*	Total Value of Marine Waters (M€)	Value per sq.km ('000€)
Cyprus	81,862	1,270	15.5
Greece	107,981	1,093	10.1
Italy	120,868	9,685	80.1
Spain	246,067	123,383	501.4

Table 1. *Total and per sq.km value of marine waters for selected Member-States*

**: According to European Parliament (2010)*

Table 2. *Total and per sq.km CoD of marine waters for selected Member-States*

Country	Area of jurisdictional waters (sq.km)*	Cost of Degradation (M€)	Other Costs (M€)	Cost per sq.km ('000€)	CoD/Value
Cyprus	81,862	148	13.3	1.8	12.7%
Greece	107,981	558	n/a	5.2	51.0%
Italy	120,868	1,543	n/a	12.8	15.9%
Spain	246,067	1,300	n/a	5.3	1.1%

**: According to European Parliament (2010)*

For instance, Spain has included the total contribution of its touristic sector. Without the touristic sector, the total value is estimated at 19.850 M€ or 80.7 thousand € per sq.km. On the other hand, estimates for Italy are underestimated because the economic value of aquaculture was not included due to lack of data regarding the added value of the sector. The same remarks are drawn as regards the estimates of the CoD. The discrepancy is quite clear when the CoD to Value ratios are considered. To wit, the CoD to Value ratio in Greece, estimated at 51%, is fifty times higher than that of Spain.The abovementioned remarks prove the necessity of establishing "common" unit values among Member States in order to mediate the discrepancies in the estimates. For illustrative purposes, Table 3 provides 'adjusted' estimates of the total and unit (i.e. per sq. km) values of marine waters for the four Member States under investigation, using the economic value of benefits estimated by Mangos et al. (2010), at Mediterranean regional level, i.e. 31.2 billion €(2012) in total that is around 12,500 €(2012) per sq. km. Furthermore, this "regional" value has been weighted according to the share of each country's GDP to the total GDP of the region in order to take socioeconomic parameters into account. These figures may not be absolutely "accurate", yet they are comparable and transparent.

Table 3. *'Adjusted' total and per sq.km value of marine waters for selected Member-States*

Country	Area of jurisdictional waters (sq.km)*	GDP (1000 million)	Original value per sq.km ('000€)	'Adjusted' value per sq.km ('000€)	Total Value of Marine Waters (M€)
Cyprus	81,862	17	15.5	0.3	25.0
Greece	107,981	182	10.1	3.3	353.2
Italy	120,868	1560	80.1	28.0	3.388.8
Spain	246,067	1023	501.4	18.4	4.524.2

**: According to European Parliament (2010)*

4. Discussion and conclusions

The estimates of the economic value and the CoD of EU marine waters are not comparable across the Member-States and, thus, the results currently available are not robust and consistent. This is attributed not only to the different approaches used but also to information gaps, lack of standardization and harmonization, differences in reporting of data, potential reporting errors, etc. (ETC/ICM, 2015). This situation could jeopardize the targets of MSFD, e.g. in case that a Member-State would seek the most 'convenient' approach to prove that additional measures are not required or are not cost-effective. To tackle with this problem and facilitate the work of marine policy and decision makers, it is necessary to homogenize the different approaches followed by the Member-States and to provide a common basis for estimating the value and the CoD of marine waters. Although this is a first step towards a more comprehensive solution, Vit could help to set common ground rules ensuring transparency and equity among the Member-States in the context of MSFD requirements.

5. Acknowledgements

This work was funded by the European Union's 7th FP for research, technological development and demonstration under Grant Agreement No. 287600 PERSEUS project (www.perseus-net.eu).

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Stakeholder Dialogue: Expectations and Feedback of the End Users of the Adaptive Marine Policy Toolbox

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Abstract

This paper presents the participatory approach and results of stakeholder consultation exercises (i.e. on-line questionnaire, face-to-face interviews, and participatory workshops) carried out within the PERSEUS stakeholder platforms (SHPs) at sub-basin and basin scales. Stakeholder consultation was used to analyse the governance framework in which the EU Marine Strategy Framework Directive (MSFD) is implemented. These consultations also provided information on the stakeholders' needs in terms of new knowledge, data, and decision support tools, thus giving the basis to prepare the technical specifications of the Adaptive Marine Policy (AMP) Toolbox, and to focus its tests and further improvements.

Keywords: Southern European Seas (Mediterranean and Black Sea), Pilot case area, Adaptive management, Policy-making, Stakeholder involvement, Stakeholder platform, Participatory approach.

1. Introduction

The “Policy” cluster is central within the policy-oriented PERSEUS project focusing on the EU MSFD principles and adaptive policies development. The objective of WP6 “Adaptive policies and scenarios” is to bridge the gaps between scientists and policy-makers, while remaining policy relevant and avoiding prescriptive endeavours. WP6 employs a participatory approach to build a ‘Science - Decision interface’ enabling a better management of human activities affecting the Mediterranean and Black Sea coastal and marine ecosystems. The goal is to assist policy-makers in facilitating and preparing future implementation of adaptive policies and management schemes in view of a better governance of the human-made pressures in the Southern European Seas (SES).

The ultimate objective is to develop a framework to support, design and implement adaptive policies towards Good Environmental Status (GES) across SES. This Adaptive Policy Framework (APF) includes both a decision support system to support policies with high uncertainties, the Adaptive Marine Policy (AMP) Toolbox (http://www.perseus-net.eu/en/about_the_apf_toolbox), and Stakeholder Platforms (SHPs). On the one hand, the AMP Toolbox is an online ‘decision support system’, which aims at providing tools to support stakeholders and policy-makers to define suitable adaptive policies for a better governance of the SES marine and coastal ecosystems. On the other hand, the role of the SHPs is double-fold: (i) to help with the design of the AMP Toolbox; and, (ii) to contribute to its test and improvement.

This paper aims at presenting the outcomes of the stakeholder consultation exercises carried out within the SHPs. These consultations provided key elements on stakeholders' needs in terms of new knowledge, data, and decision support tools expected for the implementation of the MSFD (i.e. to prepare the technical specifications of the AMP Toolbox), as well as their opinions on the AMP Toolbox (i.e. to improve the AMP Toolbox).

2. Methods: Stakeholder Platforms (SHPs) to support Stakeholder Dialogue

The ecosystem-based approach guides regional legal and policy instruments (i.e. EU MSFD, Mediterranean UNEP/MAP EcAp, Black Sea Strategic Action Plan) aiming to maintain or achieve GES in the SES. According to the Convention on the Biological Diversity, ecosystem-based management is a strategy, which recognises that change is inevitable and that management should be adaptive and involve the necessary stakeholders at the appropriate level.

In the context of this work, involved stakeholders are concerned with, or having an interest in, the marine resources and their management. They include all those who affect and/or are affected by the policies and actions regarding marine ecosystems: public sector agencies, private sector organisations, and NGOs. Their roles within the policymaking process have been described using the Rapid Policy Network Mapping approach (Bainbridge et al., 2011).

Stakeholder participation enhances the quality of environmental decisions by considering more comprehensive information inputs; "(…) *participation should be considered as early as possible and throughout the process, representing relevant stakeholders systematically.* (…) *Local and scientific knowledges can be integrated to provide a more comprehensive understanding of complex and dynamic socio-ecological systems and processes*" (Reed, 2008).

A platform is a decision-making body comprising different stakeholders who perceive the same resource management problem, realise their interdependence for solving it, and come together to agree on action strategies for solving the problem (Steins & Edwards, 1998). It is like a roundtable, where people are gathered and have multi-stakeholder dialogues; platform is close to other terms such as forum, partnership, and network, etc. A stakeholder platform brings together different stakeholders, allowing them to step out of sectoral issues and take a broader overview of the issues. A stakeholder platform can be considered as a forum of negotiation: "*In multi-stakeholder platforms, power is* (…) *dispersed in such a way that no actor dominates, and its management is not monopolized by a single actor*" (Warner, 2005).

PERSEUS SHPs are built and implemented at basin level (SES), as well as in four pilot case areas[1] in order to: (a) promote and strengthen dialogue between scientists and stakeholders (including policy-makers); (b) improve understanding of their needs and expectations; and, (c)make the AMP Toolbox suitable by taking into account these needs and expectations. The SES SHP was developed with the PERSEUS Advisory Board, which gathered representatives of key regional organisations[2], including the two intergovernmental bodies established for the implementation and follow-up of the Barcelona and Bucharest Conventions.

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[1] *Western Mediterranean (France and Spain); Central Mediterranean / Northern Adriatic (Croatia, Italia, Slovenia); Eastern Mediterranean (Aegean Sea - Saronikos Gulf, Greece); Western Black Sea (Romania and Bulgaria).*

[2] *Balkan Environmental Association (BENA), MED POL Programme (UNEP/MAP), Black Sea Commission (BSC), IOC/UNESCO, CIESM, WWF Med Programme, General Fisheries Commission for the Mediterranean (GFCM), Marine Board, European Environment Agency (EEA), as well as EC DG Environment and DG Mare.*

Exercises of stakeholder consultation aimed at: identifying priority issues at risk of not-achieving GES in the pilot case areas and at basin level, according to stakeholders; identifying the stakeholders' expectations regarding the AMP Toolbox; improving understanding of what PERSEUS should provide in terms of scientifically-based knowledge and tools; asking feedback about PERSEUS outcomes, and questioning on the suitable ways to integrate sciences into policies.

The stakeholder consultations were structured in three forms, as follows:

- Online questionnaire (January-April 2013) was a good opportunity to check the commitment of stakeholders, as well as to take into account their needs and expectations;
- Face-to-face interviews (2013-2014) with the SHPs members at the pilot cases level provided an opportunity to be more in depth regarding stakeholders' needs and expectations, and to prepare the AMP Toolbox.
- Stakeholder meetings and participatory workshops aimed at testing the AMP Toolbox to focus further improvements.

3. Results

Firstly, at a pilot case study level, stakeholder consultations enabled the definition and analysis, for each country, of the governance framework in which the MSFD is implemented, as well as stakeholders' prospects and doubts about this implementation. MSFD created great enthusiasm regarding achievement of GES, but also hesitations about the resources that will be allocated to this objective (Hendriksen et al., 2014; Ounanian et al. 2012).

Secondly, those stakeholder consultations, particularly the workshops with members of the PERSEUS Advisory Board, provided relevant information to prepare the technical specifications of the AMP Toolbox and its tests. Following such consultations it was decided to conceive the toolbox as a support mechanism, addressing policy-makers and stakeholders' knowledge and information requirements related to the implementation of innovative adaptive policies. The toolbox was designed as a web-portal[1], which assists policy-makers in structuring their problems and providing indications on where to find relevant tools and information for problem solving. This interactive application enables the user to select different pathways for the policy design according to the issues to be tackled, boundary conditions, and preferences, and to give advice for the implementation and monitoring process, easing the policy-makers' way whilst taking into account the complexity of issues. It was also recommended that the AMP Toolbox should be limited to step-by-step guidelines for adaptive policymaking, in which each step is described in detail. The AMP Toolbox was supplemented not only with examples related to the MSFD implementation, but also with tools which can be used in each phase, such as the Driver-Pressure-State-Welfare-Response framework (Cooper, 2013; O'Higgins et al. 2014), benefit-cost and multi-criteria decision analysis

Finally, in order to test the effectiveness and usefulness of the AMP Toolbox, as well as to collect valuable advice and recommendations by potential end-users for its improvement and fine tuning, a series of tests were organised at basin level and in the four pilot case SHPs. As an example, in the Northern Adriatic sub-basin, a role play game was organised with representatives from the three countries participating in this SHP. During this exercise the toolbox was used to simulate the construction of policies tackling the marine litter issue. The meeting provided insights both into policy issues connected to the problem of marine litter in a cross-border context, and also gave suggestions for improving the AMP Toolbox. In addition, participatory approaches were conducted through the development of workshops where the AMP toolbox was tested against specific use cases: e.g. Bluefin

[1] *http://www.perseus-net.eu/en/about_the_apf_toolbox/index.html*

tuna fishery and dynamic marine protected areas in Spain.

4. Conclusions

Why stakeholder dialogue? Multi-stakeholder dialogue, negotiation, compromise are always preferable to arbitrary decision because they carry acceptable for all and efficient solutions. Main outcome of Stakeholder Dialogue activities (stakeholder consultation) are as follows:

1) The examination of local governance of maritime affairs and existing schemes of coastal management, notably in terms of organisation (interactions between stakeholders concerned by the MSFD) was a prerequisite before going further regarding the policy-oriented aspects of the project. Stakeholder consultations highlighted their prospects and doubts regarding the MSFD implementation, notably for the definition of programmes of measures.

2) These consultations helped to identify stakeholders' needs in terms of new knowledge, data and tools to support policymaking. That was necessary to design and build the AMP Toolbox and to meet stakeholders' expectations, thus to test, improve and disseminate the toolbox.

3) Stakeholder Platforms contributed to dissemination and visibility of PERSEUS project's results. They participated to the "Science - Policy interface" of this policy-oriented project.

While the first round of stakeholders consultations (2012-2013) allowed to understand stakeholders' needs regarding the AMP Toolbox, the second round (2014-2015) demonstrated that the project managed to meet most of their expectations. Stakeholders showed a supportive opinion on the AMP Toolbox, notably regarding the amount of information and knowledge collected.

Experts mandated by the European Commission for the second review of the PERSEUS project stated that "(…) *the AMP is a strong component of the outreach materials providing a relatively user friendly and potentially useful tool for decision makers*". Indeed, while other European policy-oriented project (e.g. STAGES) support the MSFD implementation by developing "Science – Policy" interfaces, the PERSEUS approach is successful in focusing on stakeholders actual needs in the Mediterranean and Black Sea. This added value may be used as a model and a source of inspiration for other regions, sub-regions, and regional seas.

5. Acknowledgements

This work is part of the "Policy-oriented marine Environmental Research for the Southern European Seas" project (PERSEUS, http://www.perseus-net-eu,Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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Building regional cooperation between scientists and stakeholders in the SES non-EU countries.

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Abstract

A series of six regional stakeholders' workshops have been organized by PERSEUS non-EU partners in their countries and were facilitated by the PEREUS WP5 core team to inform national and regional authorities about the project's key outcomes. Among the fundamental goals of these workshops was to create a platform for the establishment of effective regional collaboration towards achieving Good Environmental Status (GES) in the SES by highlighting the close links between the EU's Marine Strategy Framework Directive's (MSFD) and the UNEP/MAP Ecosystem Approach (EcAp). The need to address environmental issues that constituted a key priority in each of the areas emerged, highlighting local/regional challenges, gaps, and possible solutions. Stakeholders underlined the contribution of the methods and tools developed within PERSEUS; robust scientific outcomes pertinent to environmental status assessments were considered as a key element for solid decision-making.

Keywords: Environmental status assessments, stakeholders, science-policy interface, MSFD, EcAp

1. Introduction

Within PERSEUS Work Package 5: "*Basin-wide promotion of the MSFD principles*" a series of six stakeholders' workshops (SWS) are foreseen to be organized in non-EU study areas located in different parts of the Mediterranean and Black Sea basins. The selected case studies were: the Croatian coastline (not an EU member at the onset of the programme), the Gulf of Tunis, the Moroccan coast, the Sea of Marmara and the South-western Black Sea, the South-eastern Black Sea- Georgian coast, and the North-western Black –Ukrainian coast. The Workshop series was entitled: *"Towards a Good Environmental Status of the Mediterranean and Black Sea Basins"*, and provided the opportunity to present and discuss PERSEUS project tools and outcomes, address environmental pressures and impacts in each area, and improve transnational collaboration on ecosystem-based management (EBM) contributing to the promotion of the Marine Strategy Framework Directive (MSFD) concepts directly linked with similar efforts of the UNEP/MAP under the Ecosystem Approach (EcAp).

2. Materials and methods

The duration of each workshop was in most cases two days and they were structured in three sessions, as follows: Opening Session, which was dedicated to familiarize the audience with the framework and the objectives of the workshop, along with introducing PERSEUS project; Session I: On-going efforts in the Mediterranean and Black Sea contributing to MSFD/EcAp, PERSEUS main outcomes, tools & links with other projects; SESSION II: Identifying and addressing regional challenges and opportunities under Ecosystem-Based Management approaches.

In the opening session special focus was given to the presentation of the implementation of the Marine Strategy Framework Directive (MSFD) in the Mediterranean and the Black Sea, and its links with the UNEP/MAP EcAp. Within the 1st Session the main PERSEUS outcomes and tools were presented along with complementary results from other projects conducted in each study area. The 2nd Session was the main interactive part of the workshops, giving the opportunity to the invited stakeholders to share their experience and discuss the hot issues identified in the first day of the SWS. Within this session a targeted questionnaire was distributed to the regional stakeholders in order to be filled in addressing, among others, environmental priority issues in each area, the adequacy of the area's existing monitoring activities and recommendations on how to fill in data/ knowledge gaps.
The 1st Workshop was organized in Split, Croatia, during the 5th and 6th of May 2015, and was attended by 35 participants who were representatives of governmental bodies and scientists from Academia from both EU and Non EU Countries (Croatia, Albania, Montenegro and Bosnia & Herzegovina), as well as a representative of the UNEP/MAP PAP/RAC.
The 2nd Workshop, was held in Tunis, Tunisia on the 4th of September 2015 and was attended by 21 participants who were representatives of governmental bodies, scientists from Academia and also representatives of the UNEP/MAP RAC/SPA.
The 3rd Workshop took place in Ankara, Turkey, between the 9th and the 10th of September 2015. The Workshop was attended by 31 participants, representatives of governmental bodies, NGOs, and scientists from Academia.
The 4th Workshop was organized in Tangiers, Morocco, on the 29th and the 30th of September 2015. The 35 participants were representatives of governmental bodies as well as scientists from Academia. Moreover, two more workshops are scheduled to take place one in Tbilisi (Georgia) and the other in Odessa (Ukraine) at the beginning of October and November 2015 respectively, following the same structure as the aforementioned ones.

3. Results - Key highlights

The 1st Workshop (Split, Croatia). The discussions were useful for both, stakeholders and PERSEUS representatives, and the communication/collaboration between Adriatic countries was considered of utmost importance for effectively tackling issues related to GES in the region. Indeed the SWS was attended by representatives of almost all countries surrounding the region and a variety of environmental pressures mainly linked with specific human activities were addressed (eutrophication, pollution, fisheries, invasive species). The need for common and integrated policy agreements pertinent to achieving GES at a regional basis was underlined indicating at the same time the prominent role of the Regional Sea Convention (UNEP/MAP). A key gap of knowledge seemed to arise by the lack of information in offshore areas suggesting that the implementation of suitably designed open sea monitoring constitutes a primary need. Moreover, another important recommendation supported by all participants was the promotion of joint monitoring in cross-border areas (e.g. Croatia and Bosnia-Herzegobina), which would significantly contribute to cost reduction but mainly enhance knowledge/collaboration on transboundary environmental challenges. Finally, the identified gaps in MSFD assessment elements and the need to include new parameters in MSFD assessments (i.e. in Descriptor 4: plankton components –micro food webs and bacteria- that lead processes in the water column as defined by PERSEUS experiments in the region) were also among the key outcomes.
The 2nd Workshop (Tunis, Tunisia). PERSEUS outcomes on anthropogenic pressures (fisheries, aquaculture, pollution, marine litter) and their impact on the Tunisian marine environment triggered lively debates, particularly related to threats on coastal ecosystems, and stakeholders stated that Integrated Coastal Zone Management (ICZM) is considered as a top priority in their country. The importance of conducting a common environmental initial assessment at national level that would guide a concrete coastal monitoring strategy was among the key recommendations. Moreover, innovative technologies using observing systems (e.g. gliders, satellite image maps) and their importance for environmental status assessments following PERSEUS outcomes in the area dominated part of the discussions. In fact, stakeholders highlighted the importance of solid scientific advice that should be communicated to public agencies in order to effectively address environmental issues in the frame of policy planning and decision making. Although most participants were not

aware of MSFD concepts, the workshop provided a good opportunity to discuss similarities with the UNEP/MAP EcAp highlighting the need for further harmonization under the umbrella of EBM, emphasizing once again the need of well designed monitoring systems along with the development of robust methodologies, that would provide results directly feeding into policy needs. Moreover, the SWS offered the possibility to stakeholders from different action arenas (the private sector, national environmental agencies, research institutes and universities, international bodies (RAC/SPA, JRC) to interact and exchange views on environmental challenges posed locally but also at basin-scale. In line with the latter, the leading role of the Regional Sea Convention in ensuring a harmonized, clearly structured and participatory process emerged.

The 3rd Workshop (Ankara, Turkey). The marine areas tackled were the Sea of Marmara and the southern Black Sea, and the main pressures on these ecosystems seemed to be linked with land-based sources (i.e. waste water discharges), underlining one more time the role of Integrated Coastal Zone Management (ICZM) in highly urbanized areas, but also to fishing, marine litter, as well as invasive species. Indeed, the need for adopting a multi-sectorial management approach while addressing multiple stressors on marine ecosystems was highlighted, along with the requirement to integrate between single-sector policies in order to minimize existing ambiguities between them. Monitoring activities in the area (e.g. the DEKOS Project, the PERSEUS Black Sea & Marmara pilot surveys), as well as PERSEUS outcomes referring to Black Sea ecosystem modelling caught the attention of the participants. Particularly the latter effort was considered as "state of the art" for the area, and representatives from policy institutions seemed genuinely interested in learning more about the EwE tool, providing further suggestions on other parameters (e.g. river data) which may enhance the resolution of results in coastal areas. Key points that were also discussed referred to the important data/knowledge gaps in the Black Sea and particularly to the existing different level of information between countries. Once again, the need for transnational collaboration for monitoring/assessments in the region, an emerging example being monitoring efforts within PERSEUS, and also the establishment of concrete communication platforms between decision makers and scientists was clearly stated. A common agreement between stakeholders was that effective management under an EBM approach can be achieved only through participatory and transparent collaboration between all the involved actors.

The 4th Workshop (Tangiers, Morocco). This SWS provided a good example of excellent bilateral collaboration between scientists from non-EU (Morocco) and EU countries (Spain) promoted in the frame of PERSEUS. Pressures were mainly related to coastal sources pertinent to the desalinization of seawater, as well as waste water discharges, but special reference was also made to conflicts for space use particularly in coastal areas, which underlined once again the prominent role of ICZM in the Mediterranean. However, one of the key challenges in the region, that was also considered as a key priority, referred to environmental hazards arising by maritime transport in the Gibraltar strait. Some very interesting collaborative results derived within PERSEUS were presented and it became evident that negative impacts should be tackled at the transnational level. During the discussions, it was manifested that special attention should be given to environmental processes, anthropogenic activities, pressures and their impacts on straits, where the prevailing conditions are unique. A final point that should be stressed is that the country has endorsed environmental laws under the EcAp concept, and stakeholders seemed to be inclined to collaborate and share valuable information with EU and non-EU institutions aiming to progress on environmental status assessments, the ultimate goal being the adoption of effective measures that will improve the status of the marine ecosystems in the region.

4. Conclusions

Discussions during the SWSs were very fruitful and emphasized the need for networking and collaboration at national and transnational levels among both scientists and stakeholders from different action arenas. Setting regional but also basin-wide policy agreements, but also integrate between existing and single-sector policies will contribute to effective management and enable achievement of good environmental status of marine waters. Establishment of joint monitoring programs will evaluate progress towards this direction. Knowledge sharing and collaboration between scientists at regional but also basin scale level were considered crucial, while at the same time interaction with public administrators would definitely improve decision-making. The role of the

RSCs in providing a networking platform and ensuring harmonization of scientific and policy approaches related to environmental issues has been highlighted along with the value of outcomes from research projects such as PERSEUS which enhance the interface between policy and science.

5. Acknowledgements.

This work has been funded by the EC FP7 PERSEUS Project (Grant. Agr. 287600).

Policy guidance for adaptive marine and coastal policy making

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Abstract

Adaptive policy making approaches are recommended by the Marine Strategy Framework Directive and the Barcelona Convention for policy making when based on ecosystem approaches fraught with uncertainties. Uncertainties are due to incomplete knowledge of the ecosystem, notably the future of interactions between socio-economic and the natural parts of the ecosystem. Application of adaptive policy making approaches in marine governance is still in its infancy. This paper describes the underlying concept of an Adaptive Marine Policy toolbox aimed at supporting policy makers in making marine policies adaptive, and provides insights to the contents and experimental applications of the toolbox.

Keywords: Adaptive management, ecosystem approach, learning, uncertainty.

1. Introduction

Various top level policy documents recommend ecosystem based management as the appropriate approach to marine and coastal policy making, for example it is explicitly recommended in the EU's Marine Strategy Framework Directive (MSFD) and by the Barcelona Convention EcAp initiative for the management of human activities. Nevertheless, experience shows that the implementation of ecosystem-based management approaches is complex, requiring the involvement of a great number of actors. It furthermore entails a broad range of uncertainties and needs to be able to accommodate future changes and react to new knowledge.

One aim of the PERSEUS project was to provide a policy guidance instrument to policy makers to facilitate the implementation of ecosystem-based management approaches for marine policies. This paper describes the underlying concept used for the PERSEUS adaptive marine policy (AMP) toolbox. This toolbox has been developed and tested as part of the PERSEUS project, with the aim of facilitating the implementation of adaptive policies and management schemes aimed at improving environmental quality in the Mediterranean and the Black Sea, and as a result maximising their capacity to provide ecosystem services to their surrounding populations, while fostering international cooperation with neighbouring countries.

2. Why policy support?

Measures aiming at improving the state of the marine environment can yield unexpected and or undesired results, potentially resulting in their failure to meet the objectives of halting the degradation of marine environments, or creating new environmental problems when resolving single issues.

*Marine ecosystems are complex and the changing character of interactions between human uses and their resultant pressures on marine ecosystems adds to this complexity. This incomplete knowledge about systemic interactions, as well as the incomplete knowledge about the future development of the interactions between socio-economic pressures and natural system, including climate change, increases the areas where the available knowledge is potentially insufficient for making informed decisions. (Rammel, Stagl, and Wilfing 2007).*Despite the lack of precise knowledge, decisions need to be taken in the present. Adaptive and integrated ecosystem-based management approaches, are based on principles of holistic consideration of the ecosystem. They allow for with the consideration of risks and uncertainties arising from incomplete knowledge about the ecosystem and about future pressures, and enable space for learning from experience and adjusting to new evidence. The precautionary principle, evoked among others by the Marine Strategy, requires action to be taken whenever there are threats of serious or irreversible damage to the environment regardless of a lack of scientific certainty. This means a lack of knowledge shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. Thus policies need to be able to react to new knowledge, unforeseen developments, and unplanned outcomes.

3. How can a toolbox support adaptive policy making?

Guidance documents and toolboxes are frequently used for supporting the implementation of policies dealing complex ecosystems and the interactions between social and natural systems that this entails. IMAGINE (Bell and Coudert 2005) for the management of coastal zones, or the Marine Spatial Planning Step-by-Step approach (Ehler and Douvere 2009) are successful examples of such guidance documents. Making decisions based on analysis and understanding of marine ecosystems, and the relevant interactions within these systems, can be supported by tools which assist decision makers in dealing with this complexity.

There are two different options for policy support: strongly formalized decision support systems (see for instance Leslie and McLeod 2007) based on algorithms and/or model based solutions, or toolboxes (i.e. structured collections of single tools which provide input to a greater variety of policy processes). The main difference between the two options lies in their specialization. Strongly formalized tools support decision makers by providing knowledge based inputs and insight into specific issues and can provide powerful long-term modeling with regards to single aspects of the ecosystem. In contrast to this specialization, toolboxes potentially have an advantage in terms of flexibility, versatility and control over inputs (modelling based tools often provoke a "black box" effect, suggesting the "ideal" solution among different policy alternatives). In addition, toolboxes focusing on the design of the policy process can be adapted to a greater range of issues and address different phases of policy making and can provide a better insight and understanding about the issues at stake. The PERSEUS toolbox aims at combining these two options, providing a step by step guidance for structuring ecosystem-based policy processes and describing a number of specific tools and models which can facilitate the development of single steps of these processes and support the choice of single policy measures.

The underlying principle of the toolbox is "adaptive" policy making. This means it guides users towards the design of policies which can evolve, are able to learn and adapt to changing circumstances and conditions of present knowledge, or to the changing condition of the socio-ecologic system. In environmental policy making, this is typically done by creating processes in which planning and implementation phases iteratively follow each other, and are coupled with continuous learning elements, making the monitoring of drivers, pressures, impacts and system responses an integral part of the implementation mechanisms. This principle of cyclic policy making is advised by the Marine Strategy Framework Directive, although few guidance for elaboration of programs of measures is provided. To address this lack of guidance, the AMP toolbox has been developed which provides guidance through the basic steps of a policy cycle (agenda setting, policy formulation, implementation, and evaluation or learning from experience):

In such an iterative learning or adaptive policy process, the start of a new planning phase can be triggered by new scientific knowledge, changing environmental conditions, the reaching of predefined thresholds, or, as in the case of the Marine Strategy Framework Directive (MSFD) after a predefined period of time. Every time before a new planning phase is started, the response of the ecosystem, society and economy and hence of the efficiency and effectiveness of the previous policy and measures should be evaluated. Thereby, policy makers can adapt the new planning phase with their proceeding insight, and based on the lessons learned from the successes and failures in which past policy making cycles resulted.

The capacity of policies to adapt to future conditions and changes in ecosystems and to new knowledge and information enables them to account for uncertainties like those that inevitably derive from imperfect or missing scientific knowledge, and the impossibility to foresee exactly the evolution of social and economic systems interacting with the ecosystems.

4. Looking into the toolbox

The toolbox is structured into three parts: Firstly, providing inputs and tools for policy making which are organized in a knowledgebase ("resources") containing, for example, descriptions and links to existing knowledge, such as research projects; inventories of policy measures, economic assessment studies; ecosystem based assessment studies; legal measures, etc.; secondly, a five-step guide through the policy cycle, which should help policy makers in organizing processes; thirdly, a section with best practice examples with a special focus on the Mediterranean and the Black Sea. To support the design of policy processes, the toolbox is structured as an ideal "policy-cycle" as advised by the MSFD, represented as a logical, sequential process, which starts when a problem is identified and ends with the assessment of the implementation of a logical solution or set of policy measures. This formal representation of the policy making process enables the structuring of policy making as a process, as it "disaggregates a complex phenomenon into manageable steps" (Bridgman and Davis 2003). According to this view, policy making is seen as a sequence of distinct phases, which consist of essential elements (agenda setting, policy formulation, implementation, and evaluation or learning from experience) connected to each other by feedback loops enabling learning and improvement during the policy implementation and in subsequent cycles of policy making. For the AMP toolbox the policy cycle was articulated in five steps: (1) problem identification; (2) formulation of policy options, (3) making policies robust with respect to uncertainties and adopting them, (4) implementation, and (5) monitoring and evaluation. The toolbox presents guidance for each of these five steps in the same format, including, at a first level, some basic information on the step, and at a successive level, information such as: What is the step about?; Why is the step necessary?; Who should be engaged in the step?; and What should the outcome be? In a third level, more detailed information on the design of the activities is given, as well as specific and guided access to resources and knowledge necessary for the key activities and the tools which can facilitate these activities.

The adaptive aspect of the policies is highlighted by distinguishing between the identification of policy options and the adoption of policies, providing room for choosing a combination of suitable measures and for introducing mechanisms which allow for correction and additional measures in case of unexpected outcomes, new evidence or changing environmental conditions. Furthermore, the step addressing the adoption of policies is named "making policies robust". The core objective of this step is to design sets of measures in a strategic way, including warning and correction mechanisms for an early detection and planned corrective measures, to ensure that they will yield the desired outcome, including accompanying measures or mitigation measures to support a program of measures.

5. Involvement of stakeholders and institutional learning

Among the basic conditions for the implementation of adaptive policies is the commitment of stakeholders and, most importantly, policy makers, to approaches which recognise uncertainty. Policy makers may be reluctant to recognize the existence of areas of uncertainty as this might be seen as an admission of lack of competence (Williams and Brown 2014, 469), or equally they may be unsure of how to process this uncertainty. Including stakeholders into the development of adaptive processes is crucial as, without their good understanding and commitment to the strategy, the lack of policy support will provoke failure. Finally, the institutional setting needs to allow for learning, or in other words, needs to be able to learn outcomes of monitoring and to use it for the improvement of policies. Uncertainty is difficult to handle in a policy context, and as such can tend to be overlooked.

Including stakeholders into the development of adaptive processes is crucial as, without their good understanding and commitment to the strategy the lack of policy support will provoke the failure. Finally, institutional settings need to allow for the integration of learning processes, so that the outcomes from monitoring and evaluation and experiences made during the implementation can be used for the improving policies and frameworks settings policies.

6. Stakeholder engagement and validation of toolbox

In order to engage the stakeholders, and give them ownership of the toolbox, they were closely involved in its development, ensuring both that the toolbox met their needs, and also enabling them to take possession of this tool. This process also tested the effectiveness and usefulness of the AMP Toolbox, as well as collecting advices and recommendation by potential end-users for its improvement and fine tuning. A series of tests were organized by the PERSEUS researchers at basin and at Pilot case level with the aim of improving the tool. This revised version is now freely available on the PERSEUS project web site[1] to support policy making to achieve or maintain Good Environmental Status in the SES. In the northern Adriatic a role play simulating the interactions between different groups of stakeholders was organized for the definition of a strategy tackling the problem of marine litter. The toolbox proved to be useful in this context as it provided guidance not only describing the problem, but also in assessing the uncertainty due to limited knowledge about the future dimensions of the problem and the issues related to monitoring and learning.

7. Acknowledgements

This work is part of the research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, http://www.perseus-net.eu Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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Potential application of the AMP Toolbox for designing and implementing adaptive policies in the Eastern Black Sea in the light of EU-Georgia Association Agreement

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Abstract

The article deals with the problem of application of PERSEUS Adaptive Marine Policy Toolbox (AMP Toolbox) in small non-EU countries. The short empirical analysis deals with the case of Georgia based on the experience gained by Tbilisi State University through activities associated with both SESAME and PERSEUS. Results of such analysis lead to conclusion that the actual application of AMP Toolbox might be rather restricted, based on absence of GES oriented goals and priorities in the country as well as restricted representation of local stakeholders in decision making in marine environment related programs/projects primarily originating, financed and managed externally.

Keywords: EU-Georgia Association Agreement, roadmap

1. Introduction

PERSEUS Adaptive Marine Policy Toolbox has been designed and executed as a powerful instrument for implementation of ecosystem based management. It is implicitly based on the approach that numerous actors engaged in marine and coastal policy making are able to understand the underlying idea of such policies, possess appropriate legal, policy, financial, etc. instruments, knowledge and experience or at least have access to such. This approach is well justified in case of EU based actors (and AMP is primarily aimed at them), although even in such case policy outcomes may vary do some degree depending on local conditions in implementing countries (Mediterranean vs Black sea, old and new EU member states). The situation is pretty different in non-EU states, which officially are not involved in the EU's Marine Strategy Framework Directive (MSFD), but follow it towards achieving Good Environmental Status (GES) . Here attempts to implement AMP may run into numerous obstacles ranging from refusal to acknowledge it at all to more subtle misinterpretation in order to fit it into local political agendas, even in such relatively well organized and functioning country as Georgia. Thus this paper makes attempt to provide a short empirical analysis of prospects of APF implementation in the non-EU setting.

2. AMP and Georgia/Discussion

The EC Marine Strategy Framework Directive 2008/56/EC of June 17 2008 is a legally binding document only for EC Member States in the Black Sea region (namely, Bulgaria and Romania). http://ec.europa.eu/environment/marine/international-cooperation/regional-sea-conventions/bucharest/pdf/MSFD%20Draft%20Final%20Report.pdf

In June 2014 the EU-Georgia Association Agreement (AA) including Deep and Comprehensive Free Trade Area (DCFTA) was signed signifying a totally new stage of country development. This document set up numerous rather strict policy guidelines following which "Georgia commits itself to gradual establishment of the European political, economic, social and legislative standards" (ASSOCIATION AGREEMENT 2014, Georgia's Progress Report 2014) Environmental issues play a prominent role in this document prompting the Ministry of Environment and Natural Resources of Georgia to develop "Roadmaps for EU approximation and climate action fields" in June 2015 (Roadmaps for EU 2015). Nine sector-specific roadmaps have been produced, including three on Water quality and water resources management (including marine environment, but excluding drinking water). Out of 27 activities outlined in this roadmap, five are directly connected to marine environmental problems, as follow:

3.11 draft amendments to the existing Marine Code (new environmental chapter). To comply with AA Annex requirements from EU Directive on Marine Environmental Policy. Activity to be started in 2015 and results to be in place by 01.09.2017. Donor support for this activity may be requested from ongoing EMBLAS-II project, supported by the EU.
3.23 assess the quality and prepare a programme of measures, including targets and indicators, for achieving good environmental status (GES) of the Black Sea. To comply with AA Annex requirements from Articles 5, 8-10, 13 Marine Policy Directive. Execution period app. 2017-2021. Donor support is required. EMBLAS-II outputs can be used for defining the GES and indicators at national level.
3.24 develop a monitoring programme for ongoing assessment and update targets regularly. To comply with AA Annex requirements from Articles 5 and 13 Marine Policy Directive. Years 2018-2020. Donor support is required. Planned EMBLAS-II will establish regional monitoring programme, which may be used as strong basis for national monitoring programme.
3.25 update an Integrated Coastal Zone Management Strategy. As required by DCFTA: Art.339. Activity is to be implemented in 2018-19. Donor support required.
3.27 develop a marine strategy. To comply with AA Annex requirements from Article 6 Marine Policy Directive. Activity is scheduled for 2019-20. Donor support required.

It's easy to see that Georgia does not have financial resources to implement any of the above measures (as well as almost all numerous measures mentioned in the Roadmaps), i.e. their actual implementation depends on the outside support and is not guaranteed.

Elaboration of the comprehensive set of documents that might be used to guide various actors towards adopting AMP Toolbox as working instrument in the process of achieving GES in the eastern Black Sea will take place next year basing on the results of EU funded projects (PERSEUS, EMBLAS I. II etc.). In parallel, MSFD principles, as framework document will be under implementation aiming to reach valuable and practical results for the year of 2019 (an optimistic scenario).

In pessimistic scenario, it should be taken into account the obvious reluctance of even the government policy makers to be involved in activities related to marine environment in the absence of the strong external pressure, mainly generated outside the country, lately, primarily from the EU. Some movement toward solution of marine environmental problems is observed if and when foreign financing is available and guidelines provided (mainly through basin-wide programs and projects). Thus there is no systematic approach to ecosystem-based management of marine policies. Actually there are no such standing policies in place. Thus the primary function of PERSEUS toolbox to support to adaptive marine policy, to provide guidance for policy makers can be easily derailed in the absence of the policy to support (General documentation 2014).

In addition, there is a rather well observed trend of avoiding responsibilities for participation in marine policies and the functions of various government agencies are still poorly defined. This leads to gaps in decision making procedures especially on the local level. For instance in Adjara autonomy local branch of Ministry of Environment and Natural Resources of Georgia has no authority over problems stemming from the state of marine environment. The same can be applied to any seaside located local authorities as well.

Other actors as well, especially private companies and businesses, avoid participation in any marine environment related activities to the extent of refusing to acknowledge existence of such at all. During the PERSEUS sponsored stakeholder interviews in coastal areas of Georgia in 2014 almost all targeted businesses either flatly refused to cooperate or failed to answer questionnaires, citing the absence of relation with marine environmental problems mentioned there. Such was for instance Batumi sea port administration, which refused to comment on the questionnaire claiming that they cause no environmental problems at all (sic!) and thus couldn't be involved in discussion of problems caused by others.

Thus in case of Georgia the main problem of AMP Framework implementation emerges from the shortage of stakeholders who actually care about reaching GES (AMP report 2014). There are of course numerous local NGOs and scientific establishments, who care about the state of marine environment, but they are not important enough to overcome the reluctance of especially private entrepreneurs to even acknowledge the existence of marine environmental problems related to their activities.

There are cases, when private sector, formally operating under government supervision, manages to avoid public scrutiny or the government does not always find the ways to elaborate coherent policies and incentives for business in order to combine efficiently state and private interests regarding to the state of marine environment.

This is the best illustrated by the case of anchovy fisheries, which remains the subject of controversy for at least since 2006 when the Government of Georgia issued 10 year licenses. Due to an under capacity of the local fishing vessels, 90% of total allowable catch (TAC) promptly went to Turkish companies with fishing capacity thrice the TAC Fishing Capacity, (Fishing Capacity of Georgian Anchovy Fishery 2014). While a new licensing round is due to take place in 2016, there is no indication that there is any novel government policy, enabling the local business to be engaged in more sustainable anchovy fishing combining private profit with environmental protection.

Again this situation is likely to persist at least up to 2020 until the appropriate legal base will be in place. Although the past experience related to implementation of formal rules and regulations in countries of Georgia's type, shows that these more often than not are subject of misinterpretation and even total neglect stemming from the current political conjuncture. The association agreement with EU provides some hope that the roadmaps mentioned above will be actually implemented and results of their implementation will work, but this again brings back the problem of the external pressure.

In situation like this even the problem identification often stems from approaches, understanding, knowledge originating from outside the country rather than from local interests and understanding. I.e. we primarily deal with top-down approach to problems identification originating outside Georgia. This also disturbs the PERSEUS toolbox application scheme, since tools themselves are mainly dictated by externally developed and financed projects/programs, in which local Georgian problems usually play a rather insignificant part.

The same applies to accumulation of scientific knowledge. There are numerous, again foreign financed and originated research activities, but they separately or in total do not prioritize local marine environmental problems and as such may leave some important gaps related to research, information gathering and representation.

3. Conclusions

As a result the overall situation may be described as following:

Factually, all activities associated with the state of marine environment in the Eastern Black sea area (including problem identification, policy design, policy implementation tools, etc.) aiming at achieving GES, originate outside the country, represent parts of larger programs/projects and as such are financed and managed externally.

The main (often the only) stakeholders involved in these activities are Government of Georgia bodies (primarily various branches of the Ministry of Environment and Natural Resources of Georgia based in Tbilisi, to the less extent the basin based organizations). Local academic and research bodies as well as mainly Adjara region based NGOs represent the lower level of stakeholders, who rarely actively influence the marine environment related activities. Tbilisi State University with associated organizations (e.g. S/R Firm "GAMMA Ltd.") represent the rarest of exceptions.

Business sector stakeholders are involved infrequently in activities associated with the state of marine environment, and more often, than not, actively avoid such involvement. Results of numerous programs/projects dealing with the state of marine environment rarely reach them. These actors are seldom aware of any above activities and even less bound by such.

Thus, the practical application of AMP Toolbox in the Georgian reality, despite its obvious advantages as policy planning and guidance instrument, mainly stays outside the local context. Various meetings organized within the PERSEUS or EMBLAS framework may to some extent rectify this situation, at least increase awareness of local stakeholders (again mainly representatives of government) as of tools and procedures connected to application of AFP. This in turn may lead to formation of the active position of these stakeholders as regards problem identification, selection of policy tools, formulation and implementation of policies *per se*. Efficiency of these measures however may be rather low, since there are no explicitly formulated problem vision and statement, marine strategy, policy goals and priorities associated with the GES in the Eastern Black sea area.

4. Acknowledgements

Authors express their gratitude to all persons, who directly or indirectly rendered their kind and valuable support to development of this article, namely - Nikos Streftaris, Didier Sauzade, Margaretha Breil, all Georgian respondents of 2014 stakeholder survey.

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Linking targets and cost-effective management measures for marine governance: The MeTaLi model – MERMAID project

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Abstract

The paper presents an expert judgment-based weighting framework named ‘MeTaLi’ elaborated within the framework of MERMAID project. The tool provides a cost-effectiveness ranking algorithm of alternative measures (e.g. command-and-control, economic, etc.) to assist the implementation of MSFD by means of fuzzy and stochastic analysis. An empirical application of ‘MeTaLi’ for three selected MSFD descriptors in Greece, Turkey and France is discussed, aiming to evaluate the tool and allow drawing conclusions. The paper concludes with a discussion of research findings and methodological challenges related to marine policy issues.

Keywords: expert judgment; marine policy; cost-effectiveness; MSFD

1. Introduction

It is widely acknowledged that the EU Marine Strategy Framework Directive (MSFD) is strongly framed within the economic logic. Article 13 of the MSFD expects Member States to design and implement a programme of measures to achieve good environmental status in their marine waters. Regardless of the measures selected for achieving or maintaining Good Environmental Status (GES) of marine waters, decision-makers have to define the costs of measures and to estimate the potential benefits in order to evaluate the proposed programme and the proportionality of costs by means of cost-effectiveness or cost-benefit analyses [WG-ESA 2010]. Cost-effectiveness is a more suitable approach to use when the objective has been established and the analysis focuses on the best way to meet the target. The latter seems to be the most relevant methodology in the context of Article 13 of the MSFD, where the objectives have already been established [EC 2010]. Tools that will help Member States to draw up their Programme of Measures to achieve GES are of particular importance provided that these programmes are scheduled to be developed by 2015 at the latest. This paper presents and discusses ‘*MeTaLi*’, a tool developed within the EU funded MERMAID project. *MeTaLi* provides a cost-effectiveness ranking algorithm of selected command-and-control, economic, social and technological measures using estimates that are based on expert judgment. We present an application of *MeTaLi* in Greece, Turkey and France and provide a cost-effectiveness ranking of policy measures for three selected descriptors.

2. Materials and methods

A pilot application of the tool was conducted in order to: (a) test the methodological approach; (b) evaluate its capabilities; (c) identify potential drawbacks; (d) make any necessary changes; and (e) draw conclusions and prepare guidelines for its implementation in real cases. To this end, three descriptors, i.e. chemical pollution of the environment (D8), contaminants in fish and seafood (D9) and marine litter (D10), were initially selected and examined. A strategic sample of experts was selected involving partners of MERMAID project, and various other experts with relevant scientific background and experience within the three examined descriptors. The expert panel’s composition is a crucial parameter for the successful implementation of any expert judgment survey. Thus, a well-composed and balanced sample was created consisting of 28 policy makers, physical scientists and practitioners, who were divided into three groups according to their expertise (i.e. one group per each descriptor).

The collected data are processed in order to calculate the cost-effectiveness indicator of measures for each descriptor separately according to the approach described hereinafter. The ranking of the selected measures is performed through the calculation of an overall cost-effectiveness indicator, which reflects the effectiveness, the implementation cost and the applicability of the selected measures for the specified descriptor. In addition, this indicator takes into account two additional indices, namely: (a) the frequency of selection of each measure and (b) the weighting of the degree of certainty expressed by the expert.

In order to better represent the divergence of opinions and the uncertainty involved in the estimates, the minimum and maximum values provided by the experts are combined with equal weight. Thus, expert judgments are aggregated to construct a triangular distribution, using the minimum, maximum and mode values of all experts. The fuzzy numbers are then defuzzified using fuzzy sets and integration theory by means of the centroid () of the triangular $\widetilde{B} = (a, b, c)$ distribution. At the final step, the crisp values of the cost-effectiveness indicators obtained after defuzzification from the fuzzy average estimates of the experts are normalized in a scale from 1 to 100, forming the final cost-effectiveness ranking of alternative measures for the descriptor under examination.

3. Results

The experts of each of the three groups were asked to evaluate the gap between the current situation and the fulfillment of a GES target set by MSFD for the examined descriptors. Then, they were asked to select the five most effective measures to fulfill the MSFD targets for the corresponding descriptors. Taxes and trading schemes were not selected for any of the examined descriptors, and compensation schemes were selected only once (for D10). Furthermore, two additional measures were identified for D8, namely licensing procedures with standards and common framework and education of the personnel. Regarding the most popular measures, the imposition of bans and activities controls was selected from at least 86% of the experts for all the examined descriptors, and output controls and communication and raising public awareness were selected from at least 64% of the experts, accordingly.

The implementation of the described methodology resulted in the final cost-effectiveness ranking and the normalized cost-effectiveness indicators of the examined measures. According to the final cost-effectiveness ranking list, the imposition of bans and activities controls is the most cost effective measure for descriptor D8 while the measures of communication and raising public awareness and output controls are the second and third most cost-effective. For descriptor D9, the main cost-effective measures consist of measures to improve the traceability, output controls and the imposition of bans and activities controls. Finally, the imposition of bans and activities controls seems to be the most cost-effective for the descriptor D10 followed by the measures of communication and raising public awareness and stakeholder involvement. The evaluation of the previous results should be performed taking into consideration the relative differences among the normalized cost-effectiveness indicators due to the fact that in some descriptors the most cost-effective measures are more competitive than in other descriptors.

The results of the Monte Carlo simulation process consist of various statistical measures such as mean, median, min, max and standard deviation, and the percentiles of the estimated normalized cost-effectiveness indicators of measures in order to achieve the GES. The ranking of the stochastic analysis is almost identical with the results of the basic (i.e. deterministic) analysis confirming the robustness of the obtained estimates. Specifically, there are no differences among the most cost-effective measures for the examined descriptors, while only a few minor differentiations can be observed in the final ranking of the rest of the measures

4. Discussion of results

The imposition of bans and activities controls and the output controls, which belong to traditional command and control instruments and the communication and raising public awareness, which are categorized as social instruments, were selected from the vast majority of the experts for the examined descriptors. On the contrary, economic instruments, such as taxes, trading schemes and compensation schemes were the less favoured. Hence, it seems that despite the increasing effort in recent years towards implementing market-based instruments (e.g. the "Fishing for Litter" initiatives) in support of the "polluter pays" principle, the "user/beneficiary pays" principle and the "full-cost recovery" principle, the use of command-and-control measures still dominates marine policy-making and thinking.

According to the final cost-effectiveness ranking list, the imposition of bans and activities controls is declared as the most cost-effective policy measure for descriptors D8 and D10 and the third most cost-effective for descriptor D9. The measure of output controls was the second and third most cost-effective for descriptors D9 and D8 correspondingly, and the measure of communication and raising public awareness was the second most cost-effective for both of the descriptors D8 and D10. Generally, the establishment of actions in order to quantify the potential cumulative and in-combination environmental effects triggered by the implemented measures can be considered as priority [DEFRA 2012]. Moreover, Berg et al.have suggested the rearrangement and elimination of redundant criteria and attributes in order to avoid 'double counting' in specific descriptors. To the same direction, the STAGES project targeted to analyze and model the synergistic and cumulative effects of multiple pressures for the case of fisheries and eutrophication [ICES 2014]. Hence, in cases that implementation of specific measures per descriptor is not feasible, decision makers might seek to find solutions that would generally attain the goals of MSFD for as low a cost as possible. Nevertheless, no specific and homogeneous methodology exists, so far, for the effective assessment of these effects in the examined descriptors within the framework of MSFD. To examine this issue, the overall cost-effectiveness of the examined measures was estimated taking into consideration the ranking of the measures for each examined descriptor. The obtained results confirmed the above-mentioned remarks; it seems that even though no specific note was given to the experts, the overall effectiveness of each measure was taken into consideration, at least partially, during the provision of their estimates.

Monte Carlo simulation allows the analyst to determine estimates that would be difficult to determine using deterministic analysis and, thus, can help increase the understanding of data and tackle the uncertainty involved in the estimates [Meyer and Booker 2001; Kontogianni et al 2014]. In this case, the estimated overall rank derived by the Monte Carlo analysis confirmed the robustness of the results since only minor differences exist among the ranking of the measures between the basic and the stochastic process.

4. Conclusions

The findings from the pilot-test of MeTaLi are promising. Besides establishing a priority ranking of measures just for one selected descriptor, a synthesis of the results for different descriptors may be used to help marine policy- and decision-makers determine the most 'overall' cost-effective measures. This 'overall' ranking takes could take into consideration potential synergies of policy measures between different descriptors and could prove valuable in cases that time and/or budget constraints forbid the implementation of descriptor-specific measures.

It is though evident that there exist ambiguities in the identification of the effectiveness, the implementation cost and the implementation difficulties of the measures. These are associated, among others, with information gaps, as well as the different backgrounds of the experts. Concluding it should be emphasized that the results of MeTaLi alone do not provide a final answer regarding the least-cost achievement of GES in EU marine waters. There are many dimensions (e.g. scientific, socioeconomic, etc.) that drive such decisions and should be thoroughly investigated. However, having a quantitative and transparent cost-effectiveness method could provide a key piece of the answer to the fundamental question of how to prioritize measures in the context of the MSFD when scientific evidence is lacking and - from this point of view - MeTaLi could be of enormous value to Member States that need to justify and defend their marine policy decisions on economic grounds.

5. Acknowledgements

The research leading to these results has received funding from the European Commission FP7 (ERANET/SEAS-ERA) and the General Secretary of Research and Technology (GSRT), Greece, in the framework of the project "Marine Environmental targets linked to Regional MAnagement schemes based on Indicators Developed for the Mediterranean – MERMAID" (http://www.mermaid-era.eu/home/). The authors are grateful to all scientists who participated in the elicitation process and kindly offered their valuable input.

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Extended Abstracts

ADREX campaigns with emphasis on the dense water evolution in the Adriatic pits during 2013-14: physical and biogeochemical properties

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Abstract

We describe hydrological and biogeochemical conditions during 2013 and 2014 ADREX cruises in the Middle and Southern Adriatic, and in the Northern Ionian Sea (2014).
Keywords: Adriatic Sea, Northern Ionian Sea, Dense Water, nutrients, remineralisation

1. Introduction

The significance of the Adriatic Sea and its connection with the Eastern Mediterranean are related to the processes of dense water formation and to the thermohaline and biogeochemical characteristics of the inflowing Levantine Intermediate waters (LIW).

The data collected in 2013 and 2014 show the evolution of the biogeochemical status in the Adriatic Sea after exceptionally cold winter in 2012 (Mihanović et al., 2013 [Available at www.ocean-sci.net/9/561/2013/.]). As a consequence dense, cold, and fresh waters (29.79 kg/m3, 10.00°C and 38.63) filled the Middle Adriatic Pit (MAP), and also spread southward, into the South Adriatic Pit (SAP).

2. Materials and methods

Multidisciplinary data sets were collected in March 2013, in February 2014, and October 2014 by r/v OGS Explora. Vertical profiles of T and S, plus other data from fluorometer, turbidimeter, transmissometer, and dissolved oxygen sensors were averaged over 1 decibar bin. T and density anomaly are given by potential temperature q [°C] and σ_q [kg/m^3] with reference to 0 dbar.

A 75 KHz vessel mounted Acoustic Doppler Current Profiler (VM-ADCP) was set to measure currents every 5 minutes, in cells of 8 m each within a range of about 500-550 m.

From water samples for biogeochemical analyses dissolved oxygen concentrations, dissolved nutrients (NH4, NO2, NO3, PO4 and H4SiO4), the total alkalinity and the pH, on total scale, as well as the derived parameters of carbonate system were calculated and determined.

3. Results and Conclusions

The densest waters in the SAP in 2014 have T and S within 13.07-13.13°C and 38.72-38.73, almost as those in 2013, but the dissolved oxygen content has progressively diminished as shown in Fig. 1. A concentration of all nutrients increased between 2013 and 2014 (Fig. 2), especially in the dense waters near the SAP bottom, but also in LIW. The bottom dense waters in MAP (depth > 220 m, σ_θ > 29.48 kgm^{-3}) were warmer (T~12.1°C) and slightly saltier (S~38.73) in 2014 than in 2013, probably because of the heat exchange and moderate mixing with waters above. Their oxygen content diminished to 189-191 μM. Nutrient concentrations (nitrate and silicate) increased. Due to the prolonged residence time of bottom dense water, the MAP works as a remineralization site where nutrients are regenerated due to the oxidation of organic matter by microbial activity that in turn consumes oxygen.

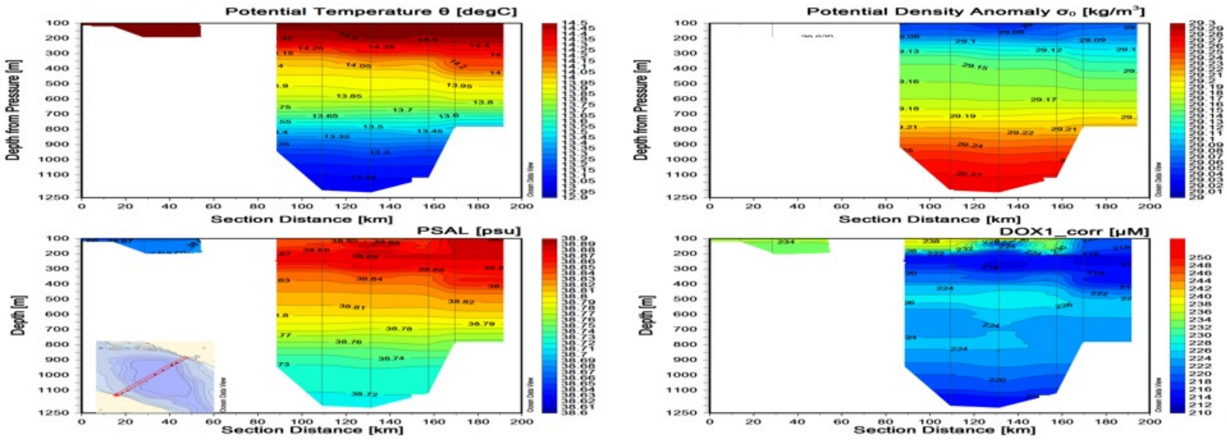

Fig. 1. *S and dissolved oxygen in the Southern Adriatic, Feb 2014.*

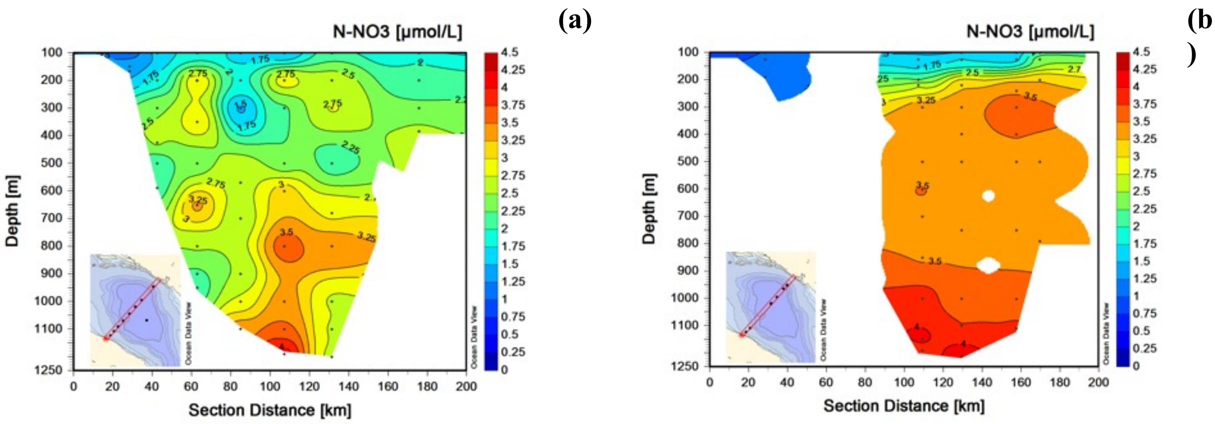

Fig. 2. *Nitrate (an example of the nutrient distribution) in the SAP: Mar 2013 (a) and Feb 2014 (b).*

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5. Acknowledgements

This research has been supported by the project: “Policy-oriented marine Environmental Research in the Southern EUropean Seas” (PERSEUS, EC 7th FP).

XBT monitoring of robust circulation features along the Genova-Palermo route

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Abstract

XBT temperature profiles collected along the Genova-Palermo route during the last 15 years are analysed, together with altimetric observations over the area, to characterize robust circulation patterns, and to study their variability. An anticyclone, just above the Corsica Channel, is found to be a recurrent feature that influences the exchanges between the Ligurian and Tyrrhenian Seas. The Bonifacio dipole is seen to display a marked interannual variability, particularly in its anticyclonic component. An anticyclonic structure is also periodically identified in the middle of the Tyrrhenian Sea.

Keywords: mesoscale processes; seasonal and interannual variability; Ligurian and Tyrrhenian Seas

1. Introduction

Over the last 15 years, a large dataset of XBT measurements by ships of opportunity has accumulated along the Genova-Palermo route, the only transect in the Mediterranean Sea that is still maintained. Analysis of this dataset, and of two decades of altimeter observations, provides information on the seasonal variability of the surface circulation structures present in the portions of Ligurian Sea (LIS) and Tyrrhenian Sea (TYS) intersected by the transect, and on changes occurred over the years. Results of recent experimental and modelling investigations (Budillon et al. 2009, Iacono et al. 2013, Napolitano et al. 2015) are also considered and a comparison is done.

2. Materials and methods

Temperature profiles are obtained using XBT probes and recording systems by LM Sippican, Inc. (USA), with a nominal global accuracy of ± 0.2 °C on temperature values. Maps of Absolute Dynamic Topography (ADT) from AVISO (http://www.aviso.oceanobs.com) are also used, which cover the whole Mediterranean Sea with a spatial resolution of 1/8°. Figure 1, showing average temperature sections and average ADT maps for the summer and autumn months, gives a good example of the information contained in the two datasets. Note that the Genova-Palermo route is shown as a black line on the ADT maps, which also display a reconstruction of the geostrophic circulation, provided by AVISO.

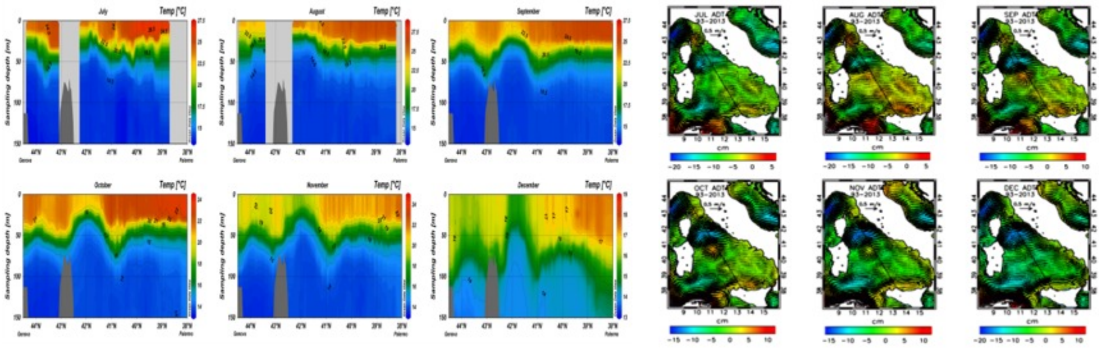

Fig.1 *Summer/Autumn vertical sections of XBT temperatures (averages over 1999-2015) vs. average ADT maps (1993-2013), with the corresponding geostrophic circulation superposed.*

3. Results

The recurrent structures individuated are better defined and appear to be more energetic during summer and autumn. A small anticyclone is found in the LIS (LA), to the northeast of Corsica, not present in the classical descriptions of the circulation in the area. The shape and position of the LA appear to affect the exchanges between LIS and TYS. In particular, some years are found in which inflow from the LIS into TYS seems to take place during summer. The anticyclonic component of the Bonifacio dipole displays a strong interannual variability, not previously recorded, with significant variations in position and shape. An anticyclone is sometimes present in the middle of the TYS, which appears to be the structure described by Budillon et al. (2009).

4. Conclusions/Discussion

The combined use of XBT and AVISO has allowed us to characterize the main circulation structures along the experimental transect, and to study their variability. Further work will be devoted to the examination of the thermal structure along the track, and of its evolution.

5. Acknowledgements

We acknowledge the support of the italian shipping company GNV and of AOML/NOAA (US).

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Response of pelagic ecosystem to deep convection in the northwestern Mediterranean (LIONEX experiment – WP1 PERSEUS)

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Abstract

The impact of convection on planktonic ecosystem in the northwestern Mediterranean has been studied through a modelling approach coupled to a huge observation program. The model was validated against hydrologic and biogeochemical parameters. A nutrient budget was calculated at the seasonal scale. Strong impacts of the intensity of convection have been shown on the annual cycle of the planktonic ecosystem.
Keywords: moduling, biogeochemical parameters, plankton, ecosystem

1. Introduction

Due to the presence of convection, the trophic regime of the northwestern Mediterranean differs from the oligotrophic character of the basin. Convection upwells large amounts of surface nutrients and reduces the light available for the photosynthesis. The planktonic ecosystem is very poor in winter despite high concentrations of nutrients. The nutrients are consumed heavily when environmental conditions are more favourable in spring. The phytoplankton bloom is then explosive. Here we study how changes in the convection could affect the plankton ecosystem.

2. Materials and methods

During the DEWEX experiment, cruises were organized at different seasons of an annual cycle with a dense network of hydrological and biogeochemical parameters. One goal was to calibrate a biogeochemical model. Here we use the 3D hydrodynamic model SYMPHONIE (Marsaleix et al., 2008) at very high resolution (1 km) coupled to biogeochemical multi nutrients model, ECO3M-S (Auger et al., 2014).

3. Results

The hydrodynamic simulation was validated with observations taken in February 2013 (Estournel et al., 2015). The timing and charcateristics of convection were well reproduced by the model. Nutrients (Fig. 1), chlorophyll and stoichiometry were also compared successfully with the observations. A nutrient budget in the surface layer was calculated over the year.

The simulation was then carried out over several years characterized by a variable convection. The amount of nutrients injected in the productive zone is highly dependent on the intensity of winter mixing. On the contrary, the annual primary production seems not to be sensitive to hydrodynamic variability. A compensation effect between winter and spring primary productions explains this result. During severe winters, the phytoplankton growth is inhibited during the intense mixing period followed by spectacular new and then regenerated productions. In warm winters, the growth of phytoplankton starts earlier and is described by a succession of moderate new and regenerated productions. The export of organic carbon at 100 m and 1000 m depths is found highly affected by deep convection intensity. Regarding the relation of the open sea deep convection area with the adjacent regions, it globally acts as a sink of organic carbon originating from shallow region by dense water cascading, and a source of organic matter for the adjacent open-seas, in particular for the Algerian subbasin.

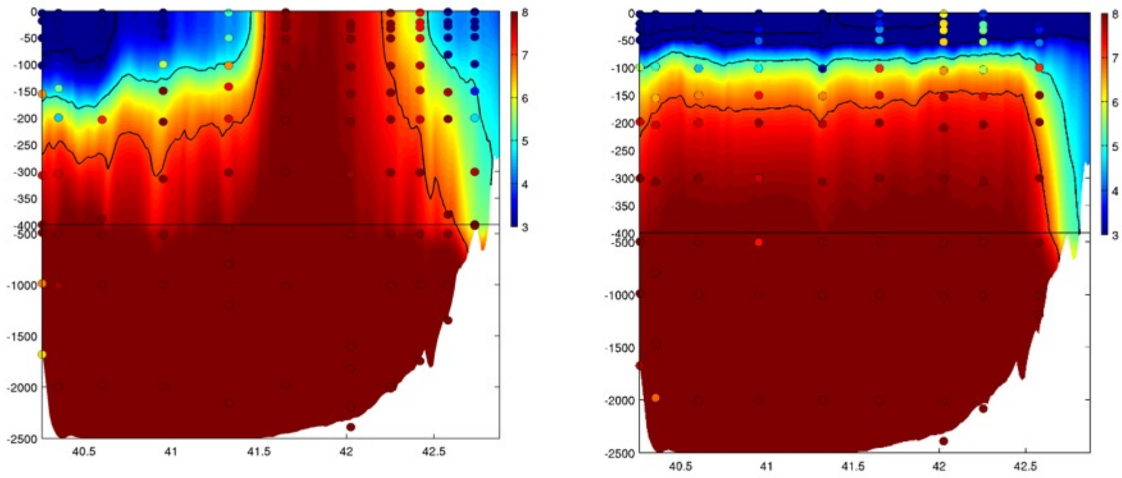

Fig.1 *Nitrate simulated (background color) and observed (dots) in winter (left) and in spring (right)*

4. Conclusions

A simulation coupling hydrodynamic and biogeochemistry was performed. An annual budget of nutrients was also done. The impact of different intensities of convection was then studied showing a significantly different phenology of plankton and large impacts on carbon export. Our results support the idea of a high sensitivity of the northwestern Mediterranean marine ecosystem to open ocean deep convection, important natural pressure potentially weakened by climate change in the next decades.

5. Acknowledgements

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The general circulation in the SE Levantine

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Abstract

The data gathered in the SE Levantine Basin from: a) the hydrographic surveys during the PERSEUS project, b) the CYBO cruises after the POEM program and c) the Argos floats and drifters during the NEMED project, along with CYCOFOS and SELIP numerical modeling, have all provided insight on the dominating flow features in the SE Levantine Basin.

Keywords: Cyprus warm eddy, Levantine Basin, mid Mediterranean jet, Eastern Mediterranean.

1. Introduction

In 1980s, during the cruises of POEM [1], it was defined a more detailed pattern of the general circulation in the Levantine Basin, consisted by several alternative cyclonic and anticyclonic eddies and gyres and an offshore cross basin jet, the Mid Mediterranean-MMJ. The dominant flow feature was identified to be a non-permanent multi-pole gyre, named as the Shikmona, consisted by few eddies, of which the Cyprus warm core one the most well pronounced [2].

2. Methodology

During the PERSEUS project, particularly within the frame of the WP3, new CTD profiles were gathered in the SE Levantine Basin. The data were collected during the CYBO and HaiSec, cruises on board the R/V Shikmona (Fig.1). Moreover, Argo floats were deployed in cooperation with the PERSEUS partner from Italy. Finally, high resolution data from the CYCOFOS and SELIPS models, coupled with the Copernicus marine service, were used to obtain the variability of the circulation, in periods beyond the cruises.

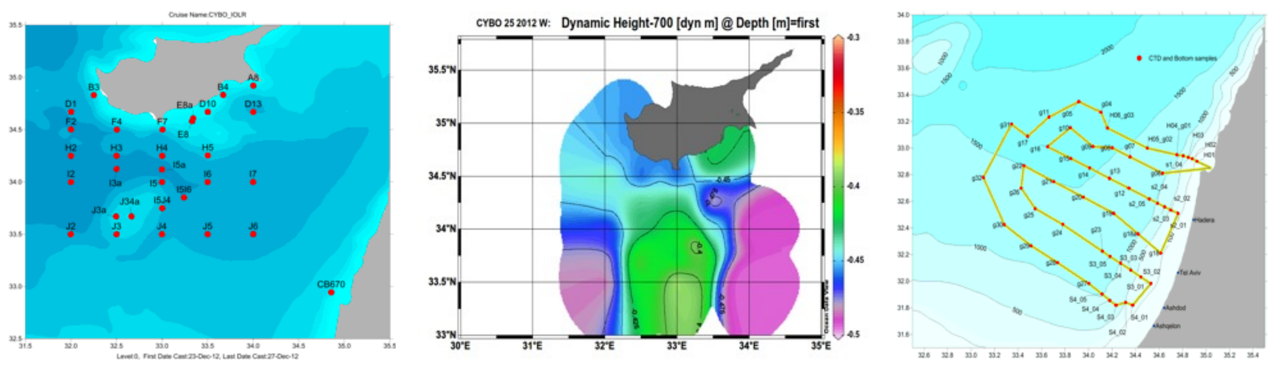

***Fig. 1**. Maps with CTD stations in the SE Levantine visited during the PERSEUS project, in the frame of the CYBO-HaiSec cruises in October and December 2012 and March 2013 and the DYH at surface/700m, during December 2012.*

3. Results and Discussion

New in-situ investigations in the SE Levantine Basin during the PERSEUS project, as well as during previous ones, such as CYBO, CYCLOPS, MSM/14 and NEMED Argo floats deployments, made possible to give strong evidences about the seasonal and inter-annual fluctuation of the MMJ, the Cyprus warm eddy variability, the Shikmona eddy generation and the periodical re-establishment of the Shikmona gyre [3,4,5].

In addition, numerical datasets from CYCOFOS and SELIPS forecasting systems, reveal that the dominant flow features in the SE Levantine is the Cyprus warm core eddy, the Shikmona eddy, which is generated during periods when the Cyprus eddy becomes weaker and or shifted westward or southward from Eratosthenes seamount, and when the strong northward current flowing along the Israel-Lebanese coast becomes unstable. The latter is evidently also from drifters trajectories, deployed during the PERSEUS project. The drifters trajectories shown an anticyclonic eddy to be detached from the prevailed northward current along the coast.

4. Conclusions

The in-situ and numerical data sets obtained in the SE Levantine from 1995-2015, provide a detailed picture of the general circulation, where: a) the Cyprus and Shikmona eddies, as well as the MMJ are the dominant flow features; b) the Cyprus warm eddy undertakes strong spatial and temporal variability; c) the variability of the displacement of the Cyprus warm eddy affects the MMJ and the eastward transfer of the AW; d) The Shikmona eddy found to be established for certain periods, when the Cyprus eddy shifts to the west, south-west; e) the MMJ flows along the northern periphery of the Cyprus eddy and is the major current transferring the AW in the area.

5. Acknowledgements

The crew of R/V Shikmona and scientists participated in the CYBO-HaiSec cruises, during the PERSEUS project.

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A deep ventilation of aerobic zone in the NE Black Sea due to vertical turbulent mixing

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Abstract

We present an observational evidence of the relatively deep ventilation event at the boundary zone of the Rim Current in the NE Black Sea in mid-autumn 2014 when the seasonal thermocline was still strong. The moored profiler data on the thermohaline stratification and the ocean currents allow us to suggest that the ventilation event was associated with the Rim Current dynamics near the continental slope. In particular, the event could be linked to intensification of the current speed in the cyclonic meander above the continental slope and, consequently, to generation of the vertical turbulent exchange.

Keywords: dissolved oxygen, Cold Intermediate Layer, suboxic zone

1. Introduction

Supply of oxygen into the permanent pycno-haloclyne is crucial for the Black Sea ecosystem because this process maintains the oxic-anoxic boundary in the stably stratified sea layer and prevents penetration of the hydrogen sulfide contamination upward to the sea surface. It is commonly thought that ventilation of the northern Black Sea aerobic zone occurs due to extensive cooling of the sea in the winter season.

2. Materials and methods

The multidisciplinary observational moored automatic mobile profiler Aqualog originally developed in SIO RAS (Ostrovskii et al., 2013) was employed as a dedicated observational mooring site of PERSEUS project in the north-eastern Black Sea. The mooring is located at the isobath of 260-270 m at the steep upper part of the continental slope offshore the Gelendzhik Bay. Since 2012 this key mooring site operates all year round. The profiler mooring provides high quality data for hydrophysiscal, geophysical and biological research (Ostrovskii and Zatsepin, 2011). It also serves as a corner stone for experimental polygon by SIO RAS in the Black Sea (Zatsepin et al., 2013). The observational data were obtained by using dissolved oxygen sensor SBE43F mounted at SBE 52-MP CTD, which was installed at the profiler Aqualog. The profiling was carried out between 35 m and 215 m 4 times per day from October 6 through December 17, 2014.

3. Results

The extensive ventilation event was observed on November 7-8, 2014. The data indicated that amount of the dissolved oxygen was higher than before or after the event by 0.2-0.3 ml/l in the oxycline at isopycnals 14.9-15.5 kg/m^3 peaking out at 1 ml/l anomaly on November 7. Noticeably at isopycnic surface of 15.9 kg/m^3, the peak absolute value of the dissolved oxygen was approximately 0.3 ml/l. The ventilation event was characterized by significant increase of the temperature by 0.2° C in the Cold Intermediate Layer (CIL) between 120 m and 160 m.

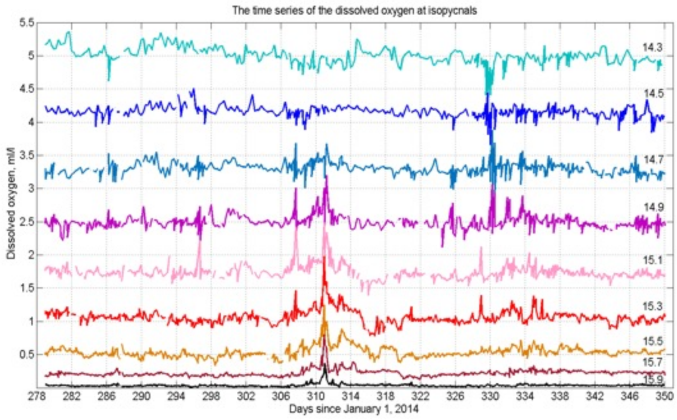

***Fig.1** Time series of the dissolved oxygen at isopycnals σ_θ.*
The extensive ventilation event is indicated by red ellipse.

The traces of similar ventilation events were found in the Aqualog mooring data of 2012-2014e.g., the ventilation resulted in disappearance of the CIL for 3 days on February 3-6, 2012. The ventilation of the pycnocline when the upper ocean is stably stratified as in November 2014 sharply differs from the convection reaching the CIL during extensive cooling at the sea surface in February 2012.

4. Discussion

In the NE Black Sea, the northwestward flow fluctuates at temporal scales of 5-15 days due to passage of the cyclonic meanders and eddies of the Rim Current (Zatsepin et al., 2013). The geostrophic adjustment of the intensified northwestward flow results in the deepening of the pycnocline. In opposite phase when the anticyclonic meanders and eddies propagate through the observational area, the southeastward current emerges and the pycnocline rises. The vertical oscillations of the pycnocline may reach 50-60 m in amplitude. Generally the oxycline fluctuations follow those of the pycnocline. The deviations of the oxygen concentration at the isopycnals are indicative of the diapycnal mixing associated with the turbulent exchange that delivers oxygen from CIL to the upper part of the pycno-halocline. The strengthening of the vertical current shear often occurs in the core of the Rim Current in the 25-50 km wide zone along the coastal boundary in the autumn and spring seasons. Thereby the observed phenomena of the extensive ventilation may play an important role in retention of the hydrogen sulfide boundary in the permanent pycno-halocline layer.

5. Acknowledgements

The help of S. Kuklev, V. Solovyev, and D. Shvoev is appreciated. The study was supported by Russian Science Foundation through grant №14-50-00095.

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Wave climate changes in the Black sea in the last years

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Abstract
The main objective of the present study is the analysis of stormy activity and accessible wave energy in the Black Sea during last 25 years. We aimed to answer the main questions: are there any trends in wave climate change of the Black Sea for the last time? What are the tendencies of wave energy redistribution which have not been addressed in the past?
Keywords: wave power; climate; Black Sea; SWAN

1. Introduction

The studies of the tendencies in the wave climate dynamics need to consider the practical efficiency of one or another method of wave energy utilization. This paper tried to give an answer - do trends in the change of the wave climate of the Black Sea exist in recent time period? What are the tendencies of wave energy redistribution over the basin of the Black Sea? In this work the trend components in the annual mean power of wind waves over the basins of the Black and Azov seas with the account for the seasons and the direction of propagation of wind waves, are estimated. The research has been performed using the methods of mathematical modeling and application of the data of experiments on the parameters of wind waves. We selected the MIKE 21 SW as the instrument of our research. A convenient user's interface is an important advantage of this model as well as wide possibilities of pre-processing and post-processing.

2. Materials and methods

We use the data set of the global atmospheric reanalysis ERA-Interim presented by the European Center for Medium-Range Weather Forecast (http://apps.ecmwf.int) to select the charts of the surface atmospheric pressure. The spatial resolution is 0.25 degree and the time step is 3 h. We determine the gradient wind from the data set of the surface pressure and then calculate the horizontal components of the standard wind by means of adjusting to a height of 10 m above the sea level ($U10$, $V10$). Thus, the ERA-Interim data make possible formation of the fields of the atmospheric pressure and wind velocity components over the given sea basin with a time step of 3 h. A three-hour time step of the initial fields of the surface pressure is an important property in the application of the ERA-Interim reanalysis. This allows us to take into account the fast cyclones whose lifetime over the sea basin is of the order of one day. The contribution of such synoptic formations to the extreme statistics of wind waves is very significant.

Verification of the model using the data of direct field observations is the starting point before application of any model. The data of the wave experiments conducted in 1996-2003 at the Southern Branch of the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences (Kos'yan et al. 1998) are the most representative data in the Black Sea. A wave measuring buoy «Directional Waverider Buoy», manufactured by the Dutch Datawell company was deployed in the coastal zone of Gelendzhik. The coordinates of the location are: 44o30'40 N, 37o58'70 E. In addition, two similar buoys were deployed near the Turkey coast (Wave Climatology of the Turkish Coast): at station Hopa with coordinates 41o25'24" N, 41o23'00" E, and station Sinop with coordinates 42o07'24" N, 35o05'12" E. Experimental wave data from the Gloria oil drilling platform (Trusca 2005), and bottom ADCP station

(Zatsepin et al. 2012) were also used in the research. The correlation coefficients between the calculated and observed rows of wave heights are in the order of 0.8-0.9.

While analyzing the results we shall apply the zoning of the Black Sea suggested in (Reference data 2006).

3. Results

1. We obtained a large amount of data of the calculated fields of wind waves in the Black and Azov seas with a time step of 3 hours that covers a period of 25 years (from 1990 to 2014). The array of calculated characteristics includes:

Spatial distribution of significant and maximum wave heights, mean wave periods, periods of the spectral maximum, and wave direction;

Frequency and frequency-direction spectra of wind waves;

Power of wind waves.

2. We obtained the storm characteristic for each region (duration, wave heights, and wave energy) as functions of seasons and direction of wave propagation. In all regions, the strongest storms are confined to the northwestern directions excluding south-western region, in which the northeasterly component is most developed.

4. Conclusions/Discussion.

The tendencies for the increase in the storm activity in the entire Black Sea are clearly seen. They are especially strong in eastern regions. The Sea of Azov with its almost zero storm trends is more conservative because its shallow depths are the limiting factor. We can state with sure that the wave activity in the Black Sea increased by 10--15% in the last 25 years. The contribution of the winter seasons is most significant in the western regions. The influence of the summer months increases in the eastern part of the Black Sea throughout the year. While considering the directions of wave propagation, we noted a clear intensification of the eastern component together with a weakening of the western component. The increase in the contribution of the eastern waves in the last 25 years is of the order of 10%; this increase is related to the entire sea. The recurrence of the waves of the southern and northern directions over the period considered here almost did not change. In the other words, the most significant changes in the Black Sea occurred on the scales of the zonal circulation.

5. Acknowledgements.

The present research was initiated by the objectives of the PERSEUS project. The field studies in 2014 and collection of data were carried out with the support of the Russian Scientific Foundation (grant no. 14-17-00547). The data processing and analysis of the literature and archive data were supported by the Russian Scientific Foundation (grant no. 14-50-00095).

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Different C pathways associated with water masses in the Adriatic Sea: should we consider the microbes for the MSFD?

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Abstract

A cruise was conducted in the Adriatic Sea in March 2013 in order to investigate the C partitioning within the heterotrophic plankton pool (from viruses to microplankton) in the middle and southern pits with the focus on microbial dynamics associated with the presence of record-breaking dense waters. The pits displayed different C pathways, with more intense C recycling within the dissolved phase probably associated with the presence of residual dense waters.

Keywords: microbial plankton, prokaryotes, dense water, Adriatic Pits

1.Introduction

In the Adriatic Sea complex hydrodynamic and atmospheric forcing during the extraordinary cold event in winter 2012 led to the formation of very dense bottom waters (Mihanović et al., 2013) which replaced old waters in the Middle and South Adriatic depressions. Here we assessed for the signature of this record-breaking event in heterotrophic carbon pathways a year after, in association with different water masses.

2. Materials and methods

Water samples were collected in March (21st to 28th) 2013 in the middle Adriatic pit (MAP) and in the deep southern one (SAP), and along a transversal coast-to-coast transect in the southern basin for the analyses of dissolved organic carbon (DOC) concentration, plankton biomass and microbial processes. Heterotrophic C production and respiration rates were measured by ^{3}H-Leucine incorporation and electron transport system, respectively (Karuza et al. 2012, 2015).

3. Results

The C biomass displayed decreasing surface-to-bottom and western-to-eastern coast gradient with the net predominance of prokaryotes among other secondary producers, especially at the western coast and in the middle Adriatic (up to 93%), whilst their contribute in the southern basin and at the eastern coast dropped to 53%. There, in turn, higher pool of heterotrophic flagellates and microzooplankton was detected. MAP was characterized by the highest biomass at all depths and mostly differed from the other stations also relatively to the C partitioning. The remnant of dense water was detected in its bottom layer (depth >170 m). There, high bacterial growth efficiency (25.7%) was coupled with exceptionally high virus abundance (indicating the presence of infection processes), thus suggesting the intense recycling of nutrients from organisms to the pool of the organic matter. Moreover, the high values of apparent oxygen demand confirm that a part of the DOC exported to depth was labile and therefore removed on short temporal scale, supporting the elevated oxygen consumption observed in this water mass. Different dynamics characterized SAP, where the decreasing values of microbial parameters were generally observed with depth.

4. Discussion/Conclusions

Hydrological features of different water masses seem to be the main driver of the variability in microbial assemblages, leading to different heterotrophic C pathways. Intense flux of the organic matter through the viral shunt was observed in the Middle Adriatic Pit, where the presence of residual dense water was detected. Still now, however, policy makers devote no attention to microbial descriptors (viruses and prokaryotes). These results support the recent proposal by Caruso et al. (2015) for the incorporation of structural or functional prokaryotic variables into several MSFD Descriptors, especially in marine ecosystems characterized by oligotrophic conditions, where prokaryotes dominate in terms of biomass and production.

5. Acknowledgements

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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The multidisciplinary ADREX survey in the Southern European Seas: the microbial biogeochemistry in the Ionian-Adriatic coupled systems.

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Abstract

With the aims to assess the microbial biogeochemistry in SES and to understand its connection with natural and/or anthropogenic pressures, the microbial signatures (biomass and metabolic rates) were analyzed in the Ionian-Adriatic system. Prokaryotes underwent fast modification of structure and metabolism within the water masses.
Keywords: Prokaryotic abundance, Metabolism, Carbon flux

1. Introduction

In Adriatic (AS) and Ionian (IS) Seas, previous microbial metabolism data has evidenced biogeochemical peculiarities of the Mediterranean waters and variability in relation to both anthropogenic pressures (e.g. eutrophication) and natural forcing. Estimates of C flow through heterotrophs are often still too unconstrained and prokaryotes still need to be included among the MSFD descriptors to advance the ecosystem assessment (Caruso et al., in press). In this work the prokaryotic metabolism and biomass in AS and IS were estimated with the aim to evaluate the functioning of such pelagic ecosystem.

2. Materials and methods

Prokaryotes abundances and volumes (PA, PAc, VOL; La Ferla et al., 2012), Picophytoplankton (PPP; Zaccone et al., 2015), Virus like particles (VLP; Broussaard, 2004), Total enzymatic activities (tEEA: GLU, LAP, AP) and free enzymatic activities (dEEA: dGLU, dLAP, dAP; Zaccone et al., 2015), Community respiration (CR; Azzaro et al., 2012), Chlorophyll a and Fluorescence; (CHLa, NF; Zaccone et al. 2015) were quantified in 13 stations in AS and IS during ADREX experiment (February 2014).

3. Results

Autotrophic measurements and pico-size dominance stated the general oligotrophy. High PA mean value of $4.6 \times 10^5 ml^{-1}$, PPP occurrence in LIW and AdDW, high tEEA in the photic layer, high ratio of LAP/GLU and high CR in the photic layers characterized AS; PA mean value of $2.6 \times 10^5 ml^{-1}$, high VLP/PAc ratios, PPP in LIW only, high dEEA mainly in the aphotic layers characterized IS. Throughout the study area, CR followed the circulatory patterns and LAP prevailed over bGLU and AP.

4. Conclusions/Discussion

Prokaryotes underwent modification of structure and metabolism within the different water masses in the Ionian-Adriatic system, acting as sentinel to natural pressures. The heterotrophic plankton metabolism assumed a key role on C fluxes and phototrophs occurrence in the aphotic layers could be linked to hydrological forcing. A preferential metabolism over the proteinaceous labile matter was observed and the high dEEA in IS suggesting a high efficiency of the microbial carbon pump. Mainly at deep layers, respiratory rates result as a good biomarker for water mass spreading. The microbial integrated approach was useful to support the knowledge of the evolutionary/cyclic scenario in the Ionian-Adriatic system.

5. Acknowledgements

The research was funded by EU_FP7 PESEUS project.

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Dissolved organic matter as a key parameter to assess the good environmental status: results from the ADREX-2014 experiment

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Abstract

Dissolved organic carbon (DOC) and chromophoric dissolved organic matter (CDOM) data, collected in the Adriatic and Ionian Sea during the ADREX-2014 cruise, confirmed that convective overturn and continental shelf pump play a crucial role in DOC export. These data suggest that the DOC exported to depth is biologically labile therefore supporting high oxygen consumption rates. Finally, the first CDOM data for this area highlight that fluorescence can be good tracers for both organic contaminants and terrestrial input.
Keywords: DOC, PAH, Deep water, Adriatic and Ionian seas, Anthropic impact.

1. Introduction

Dissolved organic matter (DOM) represents the largest reservoir of organic carbon (DOC) on the Earth and it is the main source of energy for microbes, so it plays a crucial role in the functioning of marine ecosystem. Its concentration is the result of all the biological processes occurring in the oceans and its distribution is shaped by physical processes. In addition, external inputs (atmosphere, rivers and ground waters) strongly affect its concentration. Previous studies (Santinelli 2015, Santinelli et al., 2013) suggest an important role of deep water formation in DOC export to depth in the southern Adriatic and Ionian Seas. The optical properties (absorption and fluorescence) of chromophoric DOM (CDOM) provide useful information on DOM origin and quality (humic-like, protein-like, Polycyclic Aromatic Hydrocarbons: PAH-like).

2. Materials and methods

Samples were collected in the Adriatic and Ionian Sea in February 2014, during the ADREX-2014 cruise. DOC measurements were carried out with a Shimadzu Total Organic Carbon analyzer (TOC-Vcsn). Fluorescence excitation-emission matrixes (EEMs) were measured by using the Aqualog fluorometer (Horiba), and elaborated by parallel factorial analysis (PARAFAC).

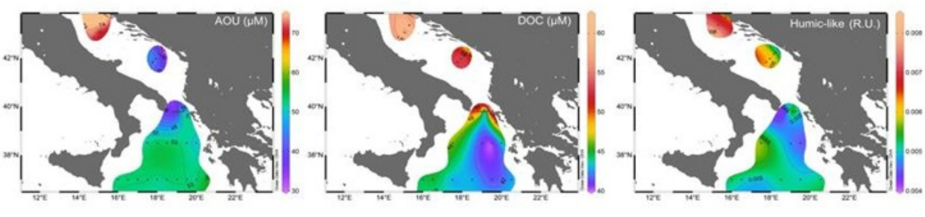

***Fig.1** Horizontal distribution of Apparent Oxygen Utilization (AOU), Dissolved Organic Carbon (DOC) and humic-like fluorescence in the bottom layer.*

3. Results

DOC and CDOM distribution in the bottom layer highlights the high concentration of DOC and humic-like CDOM in the Jabuka Pit (Fig. 1). Most of it is terrestrial, as supported by the high humic-like fluorescence usually attributed to terrestrial substances. The high values of AOU confirm that the DOC exported to depth was labile and therefore removed on short temporal scale by microbes, supporting the strong oxygen consumption observed in the bottom layer. It is also interesting to observe that if we exclude the Jabuka Pit, AOU and DOC show an opposite distribution. In the South Adriatic Pit, AOU shows a minimum while DOC shows a concentration of ~53 μM. This observation confirms the occurrence of ventilated water, rich in DOC that is exported to the Ionian Sea. Data collected during the ADREX-2014 cruise confirm previous finding that 0.85–1.19 Tg DOC yr^{-1} can be exported to depth by deep water formation and that more than 90% of oxygen consumption is due to DOC mineralization in recently ventilated deep waters. The strong increase in PAH-like fluorescence in deep waters suggests that also organic contaminants can be exported to depth by deep water formation and they can reach the abyssal Ionian Sea.

4. Conclusions/Discussion

Convective overturn and continental shelf pump play a crucial role in DOC export. The DOC exported to depth is labile, therefore supporting high oxygen consumption rates. CDOM can be a good tracer for organic contaminants and anthropogenic impact. DOC and CDOM are therefore crucial parameters to assess the Good Environmental Status and they should be considered as parameters for the Marine strategy.

5.Acknowledgments

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Anthropogenic carbon in the Southern Adriatic and Ionian Seas during the Adrex experiment.

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Abstract
Increasing concentrations of dissolved inorganic carbon (DIC) in the Mediterranean Sea are expected as a consequence of the atmospheric CO_2 rise. The resulting disparity in the dissolved inorganic carbon, referred as anthropogenic carbon (C_{ant}), has been estimated by several methods (ΔC, FCTO, TrOCA) along the water column of the Southern Adriatic and Ionian basins in 2014 (ADREX experiment) and in 2008. Results show different distributions in the two basins with the southern Adriatic affected by higher concentrations ($65<C_{ant}<105$ μm/kg) than the Ionian Sea ($30<C_{ant}<100$ μm/kg). The bottom high C_{ant} values confirm the entire water column invasion in the basins.*
Keywords: anthropogenic carbon, central Mediterranean Sea, CO_2 invasion

1. Introduction

The Mediterranean Sea has played an important role in the anthropogenic carbon C_{ant} uptake (Alvarez et al. 2005). Owing to the basin high alkalinity and low Revelle's factor waters, the Mediterranean Sea is prone to absorb more CO_2 from the atmosphere than other oceans, storing it in the basin interior via the active overturning circulation (Alvarez et al. 2014). The few existing C_{ant} estimates indicate that this marginal sea has higher concentrations than the global average (Schneider et al. 2010). Estimating the oceanic CO_2 deriving from anthropogenic activities is still a challenging process. A direct measurement of C_{ant} is not possible owing to the temporal variability, the biogeochemical process and the low anthropogenic fraction in respect to the natural carbon background. Therefore, several methods have been developed (TTD, ΔC*, FCTO and TrOCA) to infer it from other observations (e.g.: alkalinity). Here, authors present the C_{ant} distributions along the southern Adriatic and Ionian basins obtained from the 2014 Adrex (PERSEUS project) and from 2008 (SESAME project) cruises. The results will be compared for temporal variabilities.

2. Materials and Methods

Hydrological in situ properties were measured and several biogeochemical parameters, as total alkalinity, pH_T, dissolved oxygen and inorganic nutrients, were determined (Kovacevic et al., this Conference). The total alkalinity was determined by an open cell potentiometric titration with difference derivative readout and the pH, on total scale, by the spectrophotometric method. Among the several methods developed to calculate the C_{ant}, the authors applied:

- the back calculations (ΔC*, FCTO), an ensemble of methods based on the correction of the DIC in respect to the biological activity, the surface disequilibrium and the natural background
- the TrOCA approach, that relies on the Redfield's ratios by using the oxygen, total alkalinity and key nutrients as proxies for the carbon estimates.

3. Results

The results show that the C_{ant} ranges between 30 and 105 µm/kg over both basins, with higher concentration at the surface (>80 µm/kg). More in details, the South Adriatic basin exhibits the highest concentration (65<C_{ant}<105 µm/kg) that appears homogeneously distributed along the water column. The high average concentration indicates deep mixing and ventilation of the bottom layer due to the Adriatic Dense Water, either locally formed or flowing from the North shallow shelf, as also suggested by transient tracer measurements (Schneider et al., 2014). The Ionian basin exhibits lower C_{ant} values (30<C_{ant}<100 µm/kg) and more stratified vertical profiles, with a zone of minimum values (30-40 µm/kg) approximately between 750 and 1500 m. The resulting increase toward the bottom suggests an active ventilation of the basin.

4. Conclusion /Discussion

Overall, the estimates presented here match those reported for the Eastern Mediterranean (Schneider et al. 2010) with a significant C_{ant} concentration throughout the water column over the South Adriatic and Ionian seas .This confirms that anthropogenic CO_2 invasion has penetrated the bottom layers of both basins. The highest values of the Adriatic area suggest that this marginal sea might play a major role for the C_{ant} uptake and account for its distribution towards other basins via dense water spreading. The increasing amounts in the deepest layers of the Ionian Sea suggest an active dense water based ventilation of the basin, as reported by Schneider et al. 2014.

5. Aknowledgements

We thank the EC projects PERSEUS and SESAME supporting experimental activities at sea. We thank V. Kovacevic, M. Giani, S. Cozzi , G. Civitarese, for CTD, nutrients and oxygen data.

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Influence of Black Sea Water on the carbonate system in the North Aegean Sea in fall

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Abstract

Data of A_T (total alkalinity) and C_T (total inorganic carbon) collected during October 2013, in the frame of Perseus-AEGEX experiment, on a N-S transect crossing the North Lemnos basin allowed to identify the peculiarities of the CO_2 system in the North Aegean Sea in the fall.

The Aegean Sea receives high A_T and C_T loads by the brackish Black Sea Water outflowing through the Dardanelles strait and by the river runoff from the Greek and Turkish mainland. Both A_T and C_T exhibit strong negative correlation with salinity in the upper 50m of the water column. The surface waters potentially conveyed in the intermediate and deep layers, due to the thermohaline functioning and the overturning circulation of the North Aegean, carrying C_T, A_T and organic matter. The decomposition of organic matter reaching the bottom layer, leads to a significant C_T production consuming oxygen.

Keywords: total inorganic carbon, total alkalinity, carbonate system, Aegean Sea, Mediterranean Sea

1. Introduction

Although the considerable influence of the Aegean on the Mediterranean CO_2 system distribution and dynamics, there is a sparseness of reliable measurements of the carbonate system parameters. Several scattered stations were performed during the two cruises of the SESAME project in spring and late summer 2008, in north and south Aegean Sea (Souvermezoglou et al., 2010). For the first time a total of eight stations located on a transect have been sampled for the determination of A_T and C_T in the frame of Perseus-AEGEX experiment, leading to a relatively complete picture of their distribution in relation to the various water masses in the North Aegean Sea and allowing to detect the influence of the deep water formation in the CO_2 penetration in the Aegean Sea.

2. Materials and methods

Sampling was performed during October 2013 on board the R/V Aegaeo, at eight stations in the North Aegean Sea located on a N-S transect almost along 25.28°E crossing the North Lemnos basin. The seawater samples were collected according to the methods of DOE (1994) and the A_T and C_T measurements were preformed simultaneously using the potentiometric acid titration method in a closed cell at the IMAGES laboratory (University of Perpignan, France).

3. Results & Discussion

In October 2013 the extremely high concentrations of A_T and C_T recorded in the surface layer of the North Aegean coincide with the presence of low salinity BSW; these concentrations are decreasing, as the characteristics of these less saline waters are modified, through mixing with the saltier waters of Aegean and/or Levantine origin. When considering data at the layer with σθ£28.5 (the upper 50m of the water column) both A_T and C_T exhibit strong negative correlation with salinity: A_T = -44.09´Salinity + 4369.85; r^2= 0.926; n= 25 and C_T = -34.28´Salinity + 3624.86; r^2= 0.943; n= 25, depicting the high addition of A_T and C_T by the less saline waters entering the North Aegean basin by rivers and the Black Sea.

The composite θ/S diagram where the C_T concentrations were superimposed, showed that the water masses in the North Aegean can be easily characterized by their C_T concentrations. Enhanced C_T concentrations characterize the waters with σθ>29.0 filling the intermediate and deep layer of North Lemnos basin, while much more higher C_T levels sign the presence of the less dense BSW (σθ<26.54).

Dense water formation events provide important amounts of CT, AT and organic matter in the intermediate and deep layers. There is evidence that a minor formation episode occurred during winter 2012. The strong linear correlation between CT and oxygen utilisation (AOU) in the intermediate and deep layers of the study area (σθ>28.9) showed the high contribution of remineralization of organic matter to the observed concentrations of CT. The value of the CT:AOU ratio (1.817) is higher than the theoretical Redfield ratio (0.768) implying relatively high carbon release accompanied by low oxygen demand.

4. Conclusions

Data of A_T and C_T collected during October 2013, on a N-S transect in the North Aegean Sea, showed the influence of the Black Sea on the carbonate system of the North Aegean Sea. The strong negative correlation of both A_T and C_T with salinity in the upper 50m of the water column illustrates the important addition of A_T and C_T by the less saline waters entering the North Aegean basin by rivers and the Black Sea.

The water masses in the North Aegean Sea can be easily characterized using the C_T concentrations that differ from one water mass to another.

The strong linear correlation between C_T and oxygen utilisation (AOU) in the intermediate and deep layers of the study area (σθ>28.9) showed the high contribution of remineralization of organic matter to the observed concentrations of C_T.

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Tracing dissolved organic matter sources in the Dardanelles outflow through fluoresence spectroscopy

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Abstract
Black Sea Waters (BSW) seem to be the major supplier of terrestrial Chromophoric Dissolved Organic Matter (CDOM) to North Aegean Sea (NAS), which is subjected to mixing process with Levantine Waters (LW) leading to the dilution and attenuation of the fluorescence intensity of terrestrial CDOM away from the BSW frontal. Contrary autochthonous CDOM in NAS, is affected by both mixing and in situ processes.
Keywords: CDOM fluorescence, North Aegean Sea

1.Introduction

This study examines whether the information gained from fluorescence analysis could distinguish sub pools in the bulk CDOM, reflecting the different alteration state of the organic matter in NAS. The NAS, receives brackish water from the Black Sea through the Dardanelles Strait, rich in highly fluorescent dissolved organic matter (Zeri et al. 2014).

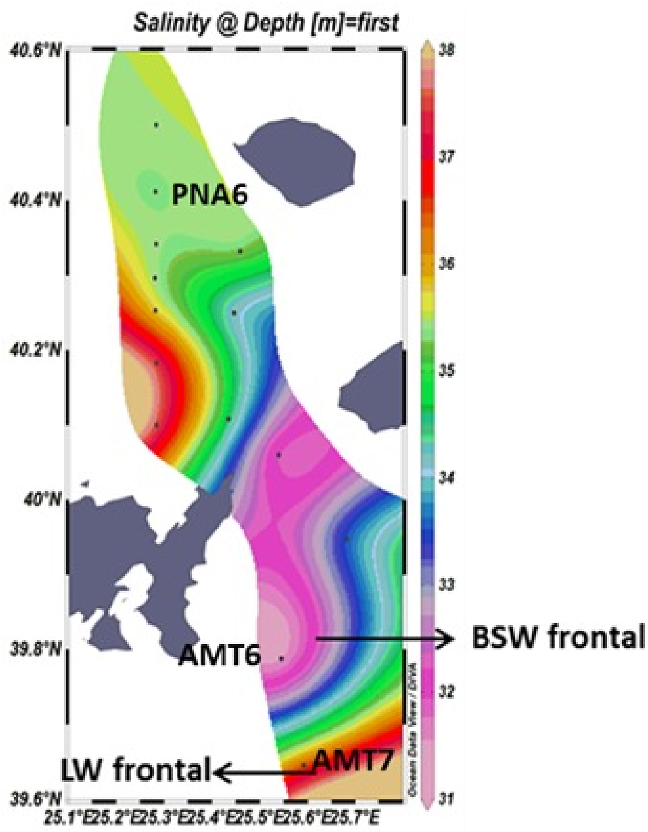

Fig. 1 *Sampled Area*

2. Materials and methods

A transect of stations was sampled in the NAS (Fig.1) during October 2013. Analysis of DOC was carried out using a HTCO automatic analyzer (Shimadzu TOC-5000). Fluorescence was measured using a Fluorolog 3-21 Jobin-Yvon fluorescence spectrometer with a 1cm cuvette, obtaining Excitation Emission Matrices (EEMs) over a range of wavelength between 250-450nm for excitation and 250-600nm for emission spectra.

3. Results - Discussion

Salinity (Fig.1) showed lower values at the surface, marking the region with the highest influence of BSW. This area is rich in both DOC and CDOM. Four fluorescent peaks were identified in the majority of the samples, representing CDOM from different origin (Fig.2). Peaks A and C indicate humic substances of terrestrial origin, while peaks T and M represent autochthonous CDOM (Coble, 1996). Peaks A and T presented in all cases the higher intensities, dominating over peaks C and M. Peak A will be used as an index of the terrestrial

CDOM while peak T will be handled as the representative of autochthonous amino acid-like CDOM. From the EEMs, it is clear that the area located at the BSW front (station AMT6, S=31.4), reveals higher intensity of the terrestrially derived component, peak A. Waters in the mixing zone (station PNA6, S=35.3) have lower intensities in all peaks; while at Levantine waters (station AMT7, S=36.8) peak T is highest. The relationships of the two fluorescence peaks with salinity, showed a strong negative correlation of S *vs* peak A (R^2=0.77, P<0.01), while no relationship was found between peak T and salinity. This observation shows that terrestrial CDOM is mainly carried to NAS from the BSW and it is largely affected by the mixing with the LW. Contrary peak T (autochthonous CDOM) showed consistently high intensities in all areas, implying that the mixing has a limited impact on autochthonous CDOM and there is a possible secondary source of autochthonous origin (primary production, bacterial alteration).

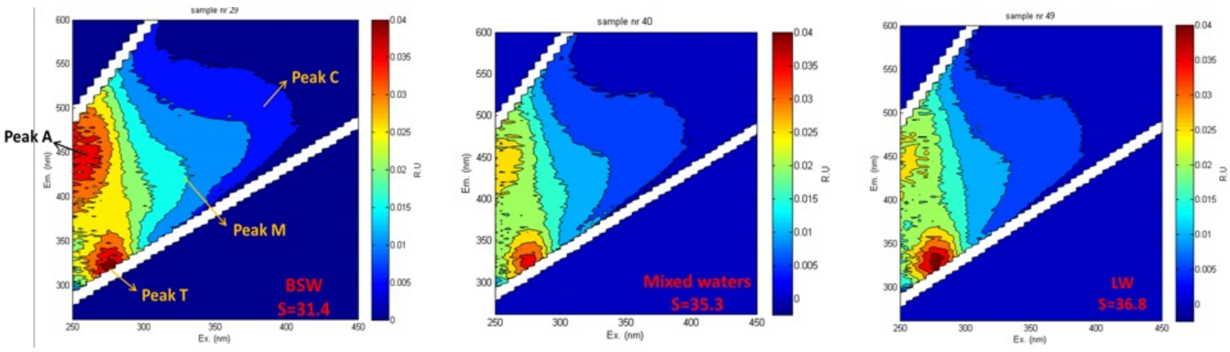

Fig. 2 *EEMs of BSW, mixed waters and LW.*

4. Acknowledgements

The present study was conducted within the framework of the European IP Project FP7 – Policy-oriented marine Environmental Research in the Southern European Seas (PERSEUS) EC Grant Agreement No 287,600 and Project Aegean MarTech, "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES. Investing in knowledge society through the European Social Fund.

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Marmara Experiment (MAREX) Results and Future Projections

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Abstract
The Marex experiment was formulated to understand recent status by evaluating the past and it consisted of one basin wide cruise and a time series station data in the Bosporus. Results obtained from the studies are shown obvious deteriorated ecological status influenced by pollution, overfishing, and decreased biodiversity. The results of the Marex experiment reveal that the continuous monitoring of the Marmara Sea is crucial and the environmental status is needed to be improved. The main indicator of the ecological status is the steepening of the nutricline between the surface and the deep waters of the Marmara Sea.
Keywords: Pollution, Ecosystem Alterations.

1. Introduction

The Sea of Marmara is receiving a substantial amount of anthropogenic pollutants from different sources within the Marmara region and through transportation from the Black Sea via the Bosphorus Strait. The Marmara region is the most density populated and industrialized area of Turkey, therefore sustainability of both economy and ecology is vital and dependent on multiple stressors and pressures. Within the scope of the PERSEUS project, a basin wide cruise (MAREX) and monthly samplings from two locations has been accomplished. Extensive chemical (nutrients and pollutants), biological and physical data from recent studies, and past data have been combined to establish MSFD descriptor parameters, such as baseline values, pristine stage etc. The nutrient fluxes between Marmara-Black Sea and Marmara-Mediterranean Sea, recent and actual species diversity, non-indigenous species distribution and abundance, and contaminant (PAH, PCB, Heavy metals) concentrations in water, sediment and organisms (Algae, Fish, Shrimp and Mussel), are revised and updated.

2. Materials and methods

Basic physical (CTD cast) chemical (Nutrients and Pollutants) and Biological (Phyto-Zoo plankton, chlorophyll, production etc.) measurements in the water column were done to evaluate recent status of the Marmara Sea compare to the past.

3. Results

General hydrographic conditions in the Sea of Marmara were determined to be virtually unchanged; therefore the general water budget of the upper and lower layers have remained unaffected, but the chemical and biological diversities were found to have altered during the last decades. The nutrient rich Black Sea inflow and discharge from Istanbul Metropolitan have enhanced organic matter production and POM abundance in the Sea of Marmara upper layer and thus POM export to the lower layer.
Deterioration in water quality of the Sea of Marmara, harmful / toxic algal blooms, mucilage events, increase of red-tides, hypoxia or anoxia events, and fish mortalities are more frequently recorded.

Specifically, 11 toxic phytoplankton species have been detected in the Sea of Marmara, since 1990 and *Noctiluca scintillans* has been identified as the most abundant heterotrophic dinoflagellate which is an indication of an unhealthy ecosystem. Zooplankton composition and abundance have also shifted, from hyponeustonic species to more pollution resistant copepod species like *Acartia clausi,* whose abundance greatly increased in fold over the last 20-30 years. In terms of abundance, *Cladocera in the Sea of Marmara in 1979 constituted only 1.1% of total summer plankton whereas in 2010 it constituted 86% with similar results being found during the last MAREX cruise in 2013. Among the jellyfish species, Aurelia aurita attained its highest biomass in the southern Sea of Marmara whilst Mnemiopsis dominated in the eastern and northern surface waters. The benthic community structure was observed to be very variable along the shelf with diversity decreasing* as the sediments became muddier.

4. Conclusions/Discussion

Comparison of long-term data indicates that both nitrate and phosphate stocks of the lower layer have increased since the 1960's as concurrent upward shifts have occurred in the oxycline and nutricline to the steep halocline. The Sea of Marmara is a sink for nitrate influx from the Black Sea. Based on past and recent data, preliminary threshold values have been determined for nutrients, nutrient ratios, secchi disk depth, oxygen saturation and chlorophyll concentration.

5. Acknowledgements

This research has been partially supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Recent oscillations of freshwater and nutrient loads of N Adriatic rivers and Danube

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Abstract

An analysis of the recent (2004-2012) river loads in N Adriatic and NW Black Sea was made in order to assess dynamics and potential effects of the continental inputs in these coastal systems. River data made available by national/international research projects and by institutional monitoring activities were collected and analyzed. They indicated that runoff and nutrient transport have been highly variable in these coastal systems during the recent years. These variations should be better considered, both at seasonal and interannual scales, as they can induce important changes in trophic levels and ecosystem structures in these areas.
Keywords: freshwater, nutrients, organic matter, hydrology, eutrophication.

1. Introduction

N Adriatic and NW Black Sea are marine systems strongly affected by river loads. N Adriatic is a semi-enclosed shallow continental shelf that receives the runoff from a drainage basin of 105500 km^2, mainly constituted by Po River. The runoff has significant consequences on the productivity and on the structure of this marine ecosystem (Giani et al., 2012). Danube is 2900 km long and its river catchment (817000 km^2) covers 33 % of the Black Sea drainage basin. Its water discharge strongly affects, together to Dniepr and Dniestr rivers, the shallow and semi-enclosed shelf of NW Black Sea. In this marine area, human-induced eutrophication has been reported as cause of extensive damages of pelagic and benthic communities (Gomoiu, 1992).

2. Materials and methods

River data of flow rates and nutrient concentration were collected in PERSEUS working areas 6 (N Adriatic) and 16 (Danube Delta) by subtask 2.3.1.a (Action 1). Quality control, harmonization of these data and estimates of river loads were also performed.

3. Results

In 2004-2012, N Adriatic rivers had an average flow of 59 $km^3\ yr^{-1}$, with periods of high regime in 2008-2010 and low regime in 2004-2007 and 2011-2012. The most important difference between the years with high (low) runoff was the presence (absence) of the peaks of flow in spring and autumn. The average flow of Danube (211 $km^3\ yr^{-1}$) was similar to that in the last 50 years. Contrary to N Adriatic rivers, Danube regime was high in 2005-2006 and low in 2007-2009, with frequent peaks in spring and low values in autumn.

In N Adriatic, TN transport increased since the 1960s, whereas TP transport was stabilized in the 1980s and reduced during the following decades. In 2004-2012, they were in the range of 113-265 kt N yr^{-1} and 4.7-13.5 kt P yr^{-1}, respectively. TN emission from Danube increased in 1950-1990 and then reduced after the early 2000s. TP emission followed a similar trend, but it was an order of magnitude smaller. In 2004-2012, the total loads of TN and TP were 284-616 kt N yr^{-1} and 11.8-40.6 kt P yr^{-1}. Both areas were subjected to highly variable nutrient transports, due to the oscillations of the runoff, and by overloads of nitrogen compared to phosphorus (molar ratios TN/TP = 48-221, DIN/PO_4 = 31-476) and silicon (Si/DIN = 0.5-1.1).

4. Conclusions

Freshwater and nutrient loads by N Adriatic rivers and Danube are important at the scale of Mediterranean and Black Sea basin. These loads change on decadal, interannual and seasonal scales, due to a combination of anthropogenic and climatic forcings, with oscillations that largely modulate productivity and eutrophication of the adjacent marine regions. In both areas, the overload of nitrogen compared to phosphorus and silicon mainly originates by the high levels of NO_3 in river waters. As a consequence, the largest pool of nitrogen is inorganic, whereas inorganic and organic pools are more equilibrated in the case of phosphorus. This unbalance of N/P ratio is the main factor that partially limits the extreme eutrophication potential of river loads in these marine systems.

5. Acknowledgements

This study was funded by PERSEUS research project. River data were obtained by institutions of Italy (ARPA, ISPRA, IRSA, AcegasAps), Slovenia (ARSO) and Croatia (DHMZ) and by international agencies and commissions of EEA, ICPDR and BSC.

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Thermohaline and nutrient dynamics in the Levantine surface and intermediate water masses, Southeastern Mediterranean Sea

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Abstract
Over the past 30 years the Levantine Surface (~0-50m) and Intermediate (~150-350m) Water masses (LSW, LIW) in the Levantine Basin (LB) displayed positive long-term trends in salinity of +0.008±0.006 and +0.005±0.003 yr^{-1}, respectively, and temperature of +0.12±0.07 and +0.03±0.02°C·yr^{-1}, respectively. Throughout the period 2002-2014 nutrient levels in the LIW core and corresponding integrated values of chlorophyll a also varied in nearly opposite phase with the decadal temperature and salinity variations. This natural variability has major implications in the definition of baseline conditions and thresholds criteria of Good Environmental Status (GES) in the LB as mandated by the Marine Strategy Framework Directive (MSFD).
Keywords: Mediterranean; seawater; salinity; temperature; nutrients; long-term trend

1. Introduction

Surface water from the Atlantic flows into the Mediterranean Sea (MS) eastward and undergoes continuous transformation due to air–sea fluxes resulting in the highest salinities in the eastern LB. The Levantine Surface Water (LSW) originates from Modified Atlantic Water (MAW) that first passes through the Ionian Basin (IB) and into the LB. Levantine Intermediate Water (LIW) formation occurs when LSW cools down and sinks along isopycnals to intermediate depths (ca. 130m<z<350m). The LIW mass flows westward across the entire basin in the opposite direction below the MAW, spreading from the LB into the IB and then into the western Mediterranean, eventually exiting the MS through the Strait of Gibraltar at mid-depth (Tanhua et al., 2013; Malanotte-Rizzoli et al., 2014; Robinson et al., 2001; Lascaratos et al., 1999). The Bimodal Oscillating system (BiOS), related to decadal reversals in the North Ionian Gyre (NIG), regulates the MAW flow to both the Southern Adriatic (SA) and the LB and has been shown to have a crucial effect on the physical and chemical dynamics in the Southern Adriatic (Civitarese et al. 2010; Gacic et al. 2010, 2011).

2. Data and Methods

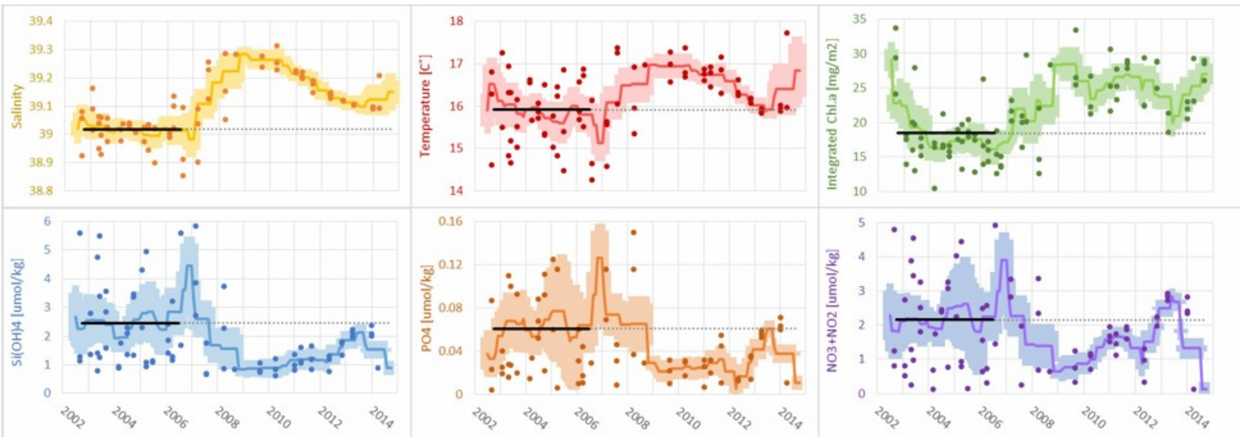
The thermohaline structure of the Southeastern Mediterranean was obtained by analyzing 1382 CTD (salinity and temperatures) profiles, covering the years 1978 to 2014 (i.e. 30 years). The data originated from the SESAME and PERSEUS cast databases. In addition, a shorter physical and chemical data set was constructed, consisting of 13 years (28 cruises) of Haifa Section cruises (2002-2014), conducted by IOLR on board the R/V Shikmona, where continuous CTD profiles of pressure, temperature, salinity, dissolved oxygen and fluorescence were collected together with Water samples analyzed for dissolved nutrients and chlorophyll-*a* (Chl-a).

3. Results and Discussion

Long-term trends - the 30 year time series of summer LSW showed a long-term increasing trend of 0.008±0.006·yr^{-1} in salinity and 0.12±0.07°C·yr^{-1} in temperature. Similarly, LIW core salinity and temperature displayed long term increasing trends of +0.005±0.003·yr^{-1} and +0.03±0.02°C·yr^{-1}, respectively (presented in poster). The rates of temperature increase in LIW are in agreement with the IPCC 2014 high end prediction for the period of 2016 to 2035 (+0.7°C or +0.035°C·yr^{-1}), which are similar in all four emission scenarios. Mean annual SST warming rates, derived from AVHRR satellite for the period 1985-2008 also agree with our findings in LIW (Skirilis et al., 2011).

Inter-annual fluctuations **-** Both LSW and LIW salinity exhibited two maximal values in 1991 and 2008. During the period of 2006-2009 As salinity and temperature values rose the nitrate+nitrite, phosphate and silicic acid levels decreased. Two time windows, before (2003-2005) and after (2009-2011) the shift in LIW properties were compared and were found to be significantly different (t-test, $p<0.01$ for all parameters) (Fig.1). The peaks of salinity in the LSW and LIW can be attributed to periods of anticyclonic circulation in the north Ionian which limited AW advection to the LB. The nutrient impoverishment of LIW can reflect a decrease in water exchange through the Cretan passage which caused a positive buoyancy flux, resulting in deeper convection during the winter and increased nutrient supply to the photic zone. The similar behavior of salinity and integrated Chl-a supports this proposition (Fig. 1) and furthermore explains the corresponding patterns of nutrient depletion and repletion in the LIW, in opposing phase to salinity and integrated Chl-a. Similar anti-phase relations, between salinity and nitrate levels were found in the southern Adriatic and northeastern Ionian (Civitarese et al., 2010).

As shown here, the physical processes (water fluxes, residence times, winter mixing depths) have significant impacts on annual and decadal variations of the related indicators (nutrients, chlorophyll a) and consequently should have major implications in the assessment of long-term and interannual primary productivity trends and in the definition or baseline conditions and criteria for human-induced eutrophication (D5) for Good Environmental Status (GES) in these basins as mandated by the Marine Strategy Framework Directive (MSFD).



5. Acknowledments

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Mechanism of horizontal and vertical exchange of nutrients driven by large-scale circulation in the Black Sea

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Abstract

The impact of the vertical and horizontal transport, which is driven by basin-scale motions, on the balance of nitrates in the central part of the Black Sea is investigated using a physical-biogeochemical box-model.
Keywords: nitrate, ammonium, transport, the Black Sea, physical-biogeochemical model

1. Introduction

Nitrogen-containing compounds are the basis of Black Sea ecosystem functioning. There is a permanent lost of nitrogen from the aerobic zone due to sinking of organic matter. These losses can be partly compensated by:

1- deep ammonium inflow from anaerobic zone due to upwelling in the central part of the Black Sea, induced by prevailing basin –scale cyclonic circulation;

2- significant amount of nitrogen-containing compounds coming to sea as a result of river discharge. Coastal water can be transported to the central part of the sea by mesoscale eddies [*Shapiro, 2010*], and due to the seasonal variability of the Ekman transport [*Kubryakova, 2013*]. Seasonal variability of a lateral transport is driven by an increase of cyclonic wind vorticity in winter which leads to Ekman divergence of waters and to their outflow from the center to the periphery and its decrease in summer-autumn which produces the water outflows from the periphery to the center of the sea.

2. Materials and methods

The biogeochemical box model of the Black Sea is presented in this work. It is based on the one-dimensional POM model [*Mellor, 2001*] which has been adapted to the Black Sea [*Oguz, 1996, Kubryakova, 2013*]. The Black Sea is divided into two areas: continental slope and deep basin. Each water area is described by one-dimensional physical-biogeochemical model.

3. Results

Nitrate from continental slope comes to the central part of the sea at the depths 30-110 m due to seasonal Ekman transport. The maximum of nitrate flux is observed in autumn-winter (fig.1, a). Horizontal turbulent diffusion induces nitrate transport from the continental slope to the central part of the sea at all depths except 60-80 m (fig. 1, b), where nitrate concentration is on average higher in the central part (fig. 2, b).

Seasonal variation of average horizontal flow of nitrate due to Ekman transport in the layer 0-120 m shows that the nitrate influx to the center is observed during whole year except May-July (Fig. 2, a). Nitrate flux due to horizontal turbulent diffusion has always positive values and is directed to the central part.

Contribution of the average horizontal flow and turbulent diffusion to the horizontal total nitrate transport is different at different depths. The horizontal transfer due to seasonal variability of the vertical velocity gives major contribution in the surface layer (~60%). Highest flux contribution induced by the horizontal turbulent diffusion (from 45 to 90%) is observed at depths of 30-100 m, where there is the largest horizontal gradients of nitrate.

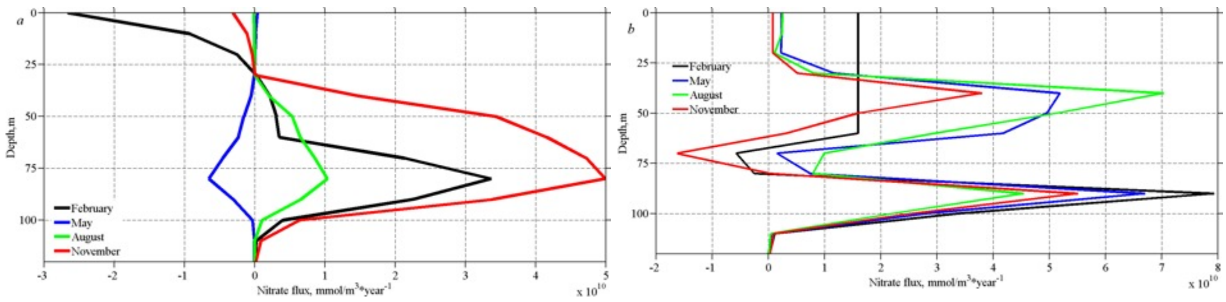

Fig.1 *Average profiles of horizontal flow of nitrate due to seasonal variability of Ekman transport (a) and the influence of horizontal turbulent diffusion (b)*

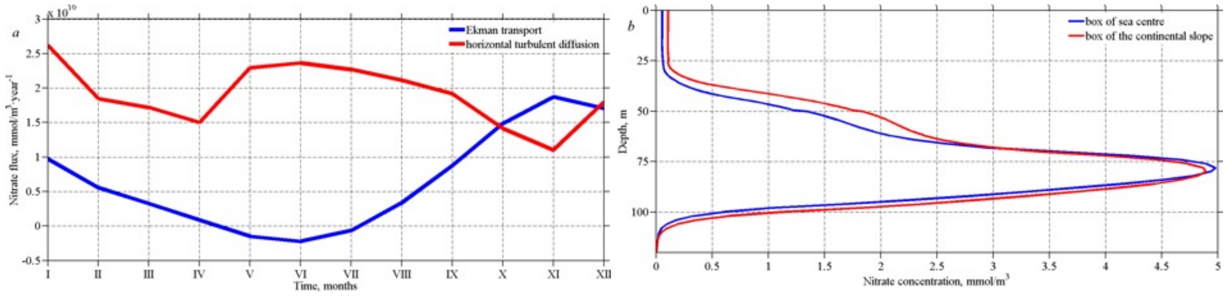

Fig.2 *a) Seasonal variation of average horizontal flow of nitrate in the layer 0-120 m from the center to the periphery; b) average nitrate profile*

4. Conclusions

The numerical experiments in the box model of the Black Sea explain the nutrients exchange between the central part of the basin and the continental slope. Intense upwelling in the central part of the Black Sea in winter and the lack of vertical motions in summer leads to asymmetry of the horizontal nitrate transport.

5. Acknowledgements

This work is a contribution to the PERSEUS Project № 287600.

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Chemical Exchanges between the Marmara and Black Seas through the Bosphorus and Impacts of the increased nutrient inputs on Marmara Two-Layer Chemistry

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Abstract

The two-layer exchange flows in the Turkish Straits System (TSS), with the associated chemical properties, dominate physical and biochemical oceanography and water qualities of the two-layer Marmara ecosystem. The present study evaluates chemical data collected systematically by the METU-IMS and IU-IMSM groups in the Bosphorus between 1987-2013 for assessing temporal changes in the concentrations and fluxes of nutrients and total organic carbon (TOC) exchanges between the adjacent seas. The impacts of the increased nutrient inputs on the Marmara Sea are also briefly evaluated.

Keywords: Marmara Sea, Black Sea, Bosphorus, Nutrients, TOC, Exchange Fluxes

1. Introduction

The less saline Black Sea surface waters polluted by the major rivers in the NW shelf, has exported large amounts of nutrients to the Sea of Marmara through the Bosporus in the recent decades. Intensive eutrophication developed in the Marmara has limited photosynthetic production to the surface layer of 5-10m and thus altered the nutricline and oxycline boundaries in the interface of Marmara two-layer system. However, no systematic data on nutrient fluxes were available until 1990's to realize the eutrophication development in the Marmara Sea. For this goal, the first estimates of the nutrient exchange fluxes between these adjacent seas were carried out by Polat and Tugrul (1995), and Tugrul et al. (2002).

2. Materials and Methods

The present study evaluates chemical data collected systematically by the two groups at the Bosphorus exits between 1987-2013 in order to calculate and discuss seasonal variations of nutrient concentrations and fluxes (DIN, PO_4; TP) and total organic carbon (TOC) exchanges between the adjacent seas of Marmara and Black Sea via the Bosporus two-layer flows (Beşiktepe et al., 1993). The results of previous studies in the Marmara Sea were also examined to assess long-term changes in the chemocline boundaries after the 1970's.

3. Results

Nutrient concentrations of the Black Sea inflow to the Marmara increased in the November-April period, showing monthly variations, but with high N/P ratios. The concentrations decreased noticeably in the late summer. Organic forms of N, P dominate the total-N, P exports by the Black Sea surface flow (BSF). The seasonality in the nutrient concentrations of Marmara lower layer waters at the Bosphorus southern exit, are much less pronounced than in the BSF.

4. Conclusions/Discussion

The winter-spring nutrient exports by BSF to the Marmara were about 4- 6 times those of the summer and autumn fluxes. However, the seasonality was less pronounced in the TP and TOC exports by BSF. The phosphate constituted about 30% of the annual TP export by BSF whilst the nitrate export was nearly 10% of the total-N export. The TOC export by BSF was about 5 times the TOC input via the Bosporus underflow. However, the increased TP export from Marmara to the Black Sea exceeded the TP input by BSF, due to P enhancement in the Marmara lower layer whilst the nitrate was partly utilized via denitrification in the oxygen-depleted lower layer, leading to low N/P ratios (8-10). The increased POM production in the Marmara surface layer of 5-10m has led to apparent upward shifts in the nutricline and oxycline to the halocline upper depths (15-30m). The nutrient-poor Mediterranean inflow to Marmara deep basin has been further enriched by at least 10-fold in nutrients by enhanced POM input from the surface layer and reach the Black Sea with high nutrient values (NO_3: 8-12 µM; PO_4: 0.7-1.2 µM; N/P: 8-10) as the oxygen has declined to the suboxic levels. In conclusion, less oxygen but more nutrients have been exported to the southwest Black Sea by the Bopshorus undercurrent since the 1980's.

5. Acknowledgements

This study was partly supported by EC-PERSEUS project. Long-term data were obtained by the national projects funded by TUBİTAK, the Municipality of Istanbul Metropolitan.

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Diagenetic processes affecting nutrient porewater profiles near the wastewater treatment plant outfall of Athens, Saronikos Gulf, Greece

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Abstract
The aim of the present work is to study the diagenetic processes occurring in the sediment at a coastal area receiving intense anthropogenic pressures. Results of porewater profiles in February and the main processes involved are presented. The downcore variability in nutrient porewater profiles as well as in nitrogen to phosphorous ratios demonstrates the diagenetic processes (e.g. denitrification, ammonification) involved. The diagenetic pathways for nutrients in shallow coastal ecosystems are important to be studied, as they affect the benthic fluxes from or to the overlying water column and thus the marine trophic status.
Keywords: diagenesis, denitrification, sewage

1. Introduction

In shallow marine ecosystems, the sediment-water exchange is often an essential nutrient source for primary producers, as sediments play a key role due to their capacity to store or release different compounds from or to the water column (Zhang et. al., 2014). Increased nutrient loads can lead to higher rates of algal production and labile organic matter delivery to the superficial sediments. Under these conditions, high mineralization rates can occur, affecting biogeochemical cycling to reactions that favor the release of large quantities of inorganic nutrients into the water column (Berelson et. al., 1998).

2. Materials and methods

Saronikos gulf is located in the Eastern Mediterranean Sea and is affected by strong anthropogenic pressures. In the study area domestic and industrial sewage and wastes are discharged after secondary treatment into the water column, potentially influencing nutrient dynamics. Sediment cores were collected near the waste water treatment plant outfall, during February 2012. Porewater samples were extracted under an inert atmosphere after centrifugation.

3. Results

In February 2012, nitrate and nitrite concentrations of porewater samples tend to decrease through the sediment column possibly due to denitrification, while ammonia concentration was increasing downcore. Ammonia was the predominant form of inorganic nitrogen. Phosphate concentrations increased downcore up to the horizon of 10 cm while their concentration decreased at the horizons 10-16 cm. The DON:DOP ratio was estimated higher than the DIN:DIP ratio.

4. Conclusions/Discussion

The profiles obtained can give us information about the diagenetic processes which take place into the sediment and influence porewater concentrations and thus the benthic flux across the sediment water interface.

The NH4:PO4 ratios are not constant and do not represent the Redfield ratio indicating that the mineralization of organic matter alone cannot explain the profiles (Anschutz et. al., 2007). Ammonia concentrations remained almost constant at the horizon 10-16 cm possibly indicating that ammonification is in equilibrium with other processes that are involved. Phosphates profile show that reactions of P removal take place below the horizon of 10 cm possibly due to P re-precipitation in the sediments.

The higher values of DON:DOP in relation to DIN:DIP are possibly suggesting loss of inorganic nitrogen or phosphate uptake. Moreover, the linear regression of ammonia to phosphate and organic nitrogen to organic phosphorous at the first 8 cm implies that the production rate of organic forms is higher, further confirming loss of inorganic nitrogen. Van Niftrik et. al. (2004), have reported that anammox bacteria were first found near a waste water treatment plant, so it is plausible that anammox process may occur at the study area, possibly coupled to denitrification.

According to our findings, the diagenetic processes occurring in the sediments strongly influence the benthic flux of nutrients to the overlying water column, thus it is important to study them in order to estimate the nutrient budget in a given marine environment.

5. Acknowledgements

This study was carried out as part of the PERSEUS project.

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Interconnections between the Danube River discharge, nutrients level and phytoplankton characteristics in the north-western part of the Black Sea (Zmiinyi Island area)

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Abstract

The results of statistical analysis of the data for 2004-2014 on the coastal waters of the Zmiinyi Island located in the north-western Black Sea 40 km far from the Danube Delta have been presented and analysed. It has been shown that the state of phytoplankton community is mostly influenced by salinity, transparency and nitrate content, whose levels are formed under the influence of the Danube discharge.
Keywords: PERSEUS, Salinity, Transparency

1. Introduction

Results of our latest studies of the coastal waters ecosystem adjacent to the Zmiinyi Island in the Black Sea (Medinets, 2014, Kovalova and Medinets, 2014, Kovalova et al., 2014) have shown that the main factor influencing the North-Western Black Sea (NWBS) water quality is eutrophication caused by nutrients input through river inflow and atmospheric transport. The objective of our work is to study interconnections between the Danube River waters discharge, nutrients level and phytoplankton characteristics in the north-western part of the Black Sea on the example of the Zmiinyi Island coastal waters.

2. Materials and methods

We analysed the data from the Zmiinyi Island Station (2004-2014) on hydrological and hydrochemical characteristics of marine environment and phytoplankton species composition, abundance and biomass, which have been measured every decade yearly from May till December. Monthly Danube River discharge data were provided by the Danube Hydrometeorological Observatory. The methods used are described in (Smyntyna et al., 2008, Medinets, 2014)

3. Results

Detailed analysis of results of our salinity studies in the Zmiinyi Island coastal waters has shown that all the data from the measured series within the limits 10.0-19.2 ‰ can be divided into three groups connected with three types of water masses: Type 1 (10.0-14.0 ‰) – water masses formed under the influence of the Danube discharge, Type 2 (14.1-17 ‰) – typical well mixed water masses from the NWBS and Type 3 (>17 ‰) – masses from open waters of the Black Sea. It was shown that the mean values of the studied characteristics in the Zmiinyi Island coastal waters, which we calculated for the above mentioned three types of water masses, had significant differences. At that, big differences were registered for characteristics of phytoplankton and nutrients. Analysis of phytoplankton community characteristics has shown that increase of the river discharge brings down water salinity significantly (2-fold) and increases the content of total, nitric and ammonium nitrogen in marine water and total abundance and biomass of phytoplankton near the island respectively 2.2, 4.7, 9.5 and 6 times. It has been shown that pollution with nutrients entering the sea with river discharge entails more than 4-fold increase in chlorophyll *a* concentration. The results of correlation and ranking analysis, which have shown the important role of the Danube discharge in forming of photosynthesis processes, as well as salinity and nutrient regime in the marine area adjacent to the Danube Delta are presented and discussed.

4. Conclusions

The studies performed have shown that the state of phytoplankton community, salinity and nutrient regimes of the Zmiinyi Island coastal waters are mostly influenced by water masses advective transport from the Danube mouth and from the open part of the sea. At that, the biggest changes happen to salinity and transparency of marine water, as well as content of nitrate, which evidences the importance and necessity of their constant monitoring in the open part of the sea, also using the TRIX.

5. Acknowledgements

The work has been done in the framework of the FP7 PERSEUS Project No. 287600 and the National projects funded by the Ministry of Education and Science of Ukraine.

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Assessment of euthrophication level in the eastern part of the Adriatic Sea

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Abstract:

The ecological status of the eastern Adriatic Sea (Croatian part) from the standpoint of eutrophication degree can be characterized as high. However, a moderate increase in eutrophication related parameters values, and thereby a reduction of the ecological status was observed in few semi-enclosed coastal bays (in Lim Bay, as well as in Bakar, Šibenik and Kaštela Bays) and central part of the NA (Po River - Rovinj transect).

Keywords: Northern Adriatic (NA), Middle Adriatic (MA), South Adriatic (SA)

1. Introduction

Significant increase of eutrophication was recorded in the Adriatic Sea in the second half of the 20th century (Šolić et al., 1997; Degobbis et al., 2000; Marasović et al., 2005). In the first decade of the 21st century, a considerable decrease of eutrophication in the Adriatic waters was observed (Šolić et al., 2010; Giani et al., 2012). Both phenomena were attributed to the combined impact of anthropogenic pressures and climate changes.

Table 1. *Minimum, maximum and average values for oxygen saturation, concentration of total phosporous (Thps), total inorganic nitrogen (Tini) and chlorophyll a (Chla), and trophic indeks (TRIX) in the surface layer (< 11 m) for four areas along the eastern Adriatic in 2013.*

Parameter		NA (A 18-21)	MA(A 9-11)	Kaštela Bay	SA (A 1-3)
Oxygen saturation [%]	Min	92.0	99.30	102.16	94.40
	Max	168.0	136.30	124.70	112.40
	Average	105.2	109.20	111.20	105.70
c(Thps) [μmol L^{-1}]	Min	0.09	0.07	0.10	0.10
	Max	0.42	0.31	0.27	0.38
	Average	0.17	0.16	0.19	0.19
c(Tini) [μmol L^{-1}]	Min	0.27	0.61	0.74	0.99
	Max	15.77	3.75	5.75	3.79
	Average	2.27	1.58	2.41	2.26
c(Chl$a$) [μmol L^{-1}]	Min	0.06	0.01	0.19	0.05
	Max	3.27	0.94	1.37	0.68
	Average	0.61	0.27	0.74	0.26
TRIX	Min	1.87	1.95	3.02	2.43
	Max	5.92	4.17	4.44	3.81
	Average	3.15	2.96	3.73	3.08

2. Materials and methods

Samplings and measurements were performed during 2013 (nine cruises in the NA, seven cruises in the MA, and five cruises in the SA). Methods of measurements and analyses were as follows: temperature and salinity (CTD probe SeaBird SBE-9), nutrients (Parsons et al.,1984), dissolved oxygen (ISO 5813, 1983), chlorophyll a (Strickland and Parsons, 1972), abundance and composition of phytoplankton (Utermöhl, 1958).

3. Results

Assessment of the ecological status from the standpoint of degree of eutrophication was based on the approach used for the BQE Phytoplankton in the frame of the WFD, also partially embedded in the GES assessment for D5. Data are presented in Tables 1 and 2.

Table 2: *Frequencies of phytoplankton abundances occurrence at all investigated stations in the water column (cell l^{-1})*

Lower bound	Upper bound	Frequency	Relative frequency
0	66001	228	0.621
66001	132002	77	0.210
132002	198003	27	0.074
198003	264004	15	0.041
264004	330005	8	0.022
330005	396006	2	0.005
396006	462007	7	0.019
462007	528008	1	0.003
528008	594009	1	0.003
594009	660010	1	0.003

Phytoplankton community composition, as well as the relationship between the abundances of diatoms and dinoflagellates confirm high ecological status of the eastern Adriatic.

4. Conclusions

The existence of the oligotrophic environmental conditions was confirmed in almost all parts of the eastern Adriatic Sea. The usual physical and chemical conditions were not significantly modified even in the areas where eutrophication occurred occasionally, such as in Lim Bay as well as in Bakar, Šibenik and Kaštela Bays. In addition, low concentrations of dissolved and particulate organic matter in the whole investigated area confirm that GES (regarding D5 – Eutrophication) is almost reached in coastal and open waters of the eastern Adriatic Sea.

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Harmful and Toxic Marine Phytoplankton in coastal waters of the Zmiinyi Island in the North-Western part of the Black Sea (2012-2014)

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Abstract
Data on Harmful and Toxic Marine Phytoplankton (HTMP) in the Zmiinyi Island coastal waters are presented and analysed. During spring-autumn 2012-2014 55 HTMP species were observed which made 20,,8% contribution to the 265 total number of species. Among HTMP species, there were 28 species of Dinophyta and 14 species of Bacillariophyta. As compared to 2004-2011 period, more extensive blooms caused by harmful species Bacillariophyta (especially Pseudo- nitzschia) and Cyanobacteria (Microcystis) took place. Significant changes in the structure of phytoplankton species composition were revealed.
Keywords: Zmiinyi Island, phytoplankton, harmful species, Bacillariophyta, Dinophyta

1. Introduction

Negative effects of excessive development of Harmful and Toxic Marine Phytoplankton (HTMP) species include toxicological impact on flora and fauna, disturbance of the marine ecosystem's food webs, especially considering the Black Sea (Krakhmalny *et al.,* 2012, Medinets *et al*., 2011). The Zmiinyi Island which is located 40 km far from the Danube Delta is one of such reference areas, as anthropogenic influence in its coastal waters is minimal (Smyntyna *et al*., 2008). The aim of the research was to study the structure of phytoplankton community, especially HTMP and Cyanobacteria, in the coastal waters of the Zmiinyi Island, during 2012 -2014.

2. Materials and methods

Marine phytoplankton has been sampled and processed in the Zmiinyi Island area by the staff of Marine Research Station (MRS) "Zmiinyi Island" of Odessa National I.I. Mechnikov University, using methods described in Smyntyna *et al*. (2008). Taxonomic determination of potentially toxic and toxic species was made in accordance with Moestrup *et al*. (2015) and Ryabushko (2003).

3. Results

During spring-autumn 2012-2014, 55 HTMP species were observed which made 20,8 % contribution to the 265 total number of species. Among HTMP species, there were 28 species of Dinophyta and 14 species of Bacillariophyta and also species of Chlorophyta and Cyanobacteria, Euglenophyceae, Haptophyta, Chrysophyceae, Dictyochophyceae and Ebriophyceae. Such species as *Heterocapsa triquetra* (Ehr.) Stein, *Noctiluca scintillans* (Mac.) Kof. et Sw., *Skeletonema costatum* (Grev.) Cl., *Pseudo-nitzschia delicatissima* (Cl.) Heid. et Kolbe, *Emiliania huxleyi* (Lohm.) Hay et Mohler, etc. should be specially pointed out as those having threatened the ecosystem during massive scale algae bloom. Abundance of HTMP species of Bacillariophyta in most samples which were collected during 2012-2014 comprised 50-100 per cent out of the total phytoplankton abundance and was reaching their bloom levels in spring and early summer.. Moreover, we can point out that the phytoplankton community during last three years exhibited some peculiar characteristics such as the increase in maximal abundance and biomass values for species as *Cerataulina pelagica*, *Chaetoceros curvisetus, Pseudosolenia calcar avis, Skeletonema costatum,* etc. which exceeded significantly (10-100 times) the maxima of the previous years. The increase in the abundance of HTMP Dinophyta from other parts of the sea is also raising a concern, since adaptation of these species to the island coastal waters conditions could impair normal development of the ecosystem's trophic structure (Dereziuk, 2012).

4. Conclusions

Through the analysis of all our observations for 2004-2014, we have established a data set of 412 species of phytoplankton (including cyanobacteria), 64 of which (15.5 %) were HTMP species. More specifically, in the periods 2004-2011 and 2012-2014 the number of HTMP species registered were 59 (17.0% of 348 species) and 55 (20.8 %of the 265 species), respectively. During the past 3 years, 66 species of microalgae and cyanobacteria were observed in the Zmiinyi Island coastal waters, which have never been registered before in the area.

5. Acknowledgements

The work has been done in the framework of the international FP7 PERSEUS Project No. 287600 (2012-2014) and the National projects (2003-2014).

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Assessing Biodiversity in the Southern European Seas countries within the PERSEUS project

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Abstract

An attempt to compile and analyze the assessment elements already in use and the newly developed by the SES countries in support to the MSFD Biodiversity descriptor (D1) has been made within the PERSEUS project (WP5). Some of the results are summarized below focusing on the state and the progress made in this direction. This document is aiming to be also a position paper that advocates for further research and cooperation on the difficult issues raised by the assessment of Biodiversity.
Keywords: Ecosystem approach, indicators, monitoring

1. Introduction

Biodiversity poses in all SES countries, a series of challenges related to methodologies and indicators used for its assessment. From species to habitats and ecosystem all should be integrated in a unitary assessment leading to an ecosystem approach. The Marine Strategy Framework Directive (MSFD) identifies biological diversity as an important descriptor to ensure Good Environmental Status (GES) in European Seas, which is defined as "*Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions"* (CEC, 2008).

2. Materials and methods

This analysis is based on the information provided by the EU countries in their Initial Assessment Reports (pursuing to Art.8 (1) of MSFD) and by non-EU countries, which have been approached through questionnaires in the form of excel template. There were 10 SES EU countries (Greece, Cyprus, France, Italy, Spain, Romania, Bulgaria, Germany, Belgium, and United Kingdom) and 6 non-EU ones (Georgia, Ukraine, Turkey, Tunisia, Croatia, Morocco) analyzed from both Mediterranean and Black Sea. The outputs from each country represented more or less the level of knowledge/expertise of the partners of Perseus had at that time.

3. Results

PERSEUS efforts towards integration of information on MSFD assessment elements Assessment of 'biological' Descriptors (Biodiversity, Non-invasive species, Commercial species and Food-webs) turned out to be, compared to the contamination or pressure descriptors, one of the most complex processes in all countries. The gaps mainly came from the lack of methodologies to assess not necessarily the biological components but their ecological characteristics pursuing to Art 8, 9, 10, 11 of the MSFD. Even in the countries with a longer tradition in ecosystem approach such as the EU Mediterranean countries, which based their assessment mainly on the Barcelona Convention and its Protocols and EcAp indicators, and WFD, this has been proved challenging. The Biodiversity descriptor is lacking a unitary approach concerning the ecological level of assessment in terms of species, habitats and ecosystem, but major difficulties have also been met in setting the GES and targets for achieving it. The countries from the Black Sea basin based their assessment mainly on the WFD, Habitat Directive and ecological quality objectives (e.g., EcoQ2) established through the 2009 Black Sea SAP. However, the Biodiversity descriptor is little developed, in spite of the availability of long monitoring available data.

New assessment elements and methodological approaches developed by SES countries

Within the WP5, there was also a commitment on doing more than analysing the existent MSFD criteria and indicators within the SES countries but also to colaborate with the other WPs in order to provide a comprehensive view on the progress of development within PERSEUS of new assessment elements. The PERSEUS vision was reflected in the way that the entire process has been conducted: from analysis of gaps, pressures and impacts on coastal and open sea ecosystems, going through the process of identifying the technological needs for the best data acquiring and up to the modeling of complex ecosystem procesess (e.g.,food webs). The key issues tackled related to Biodiversity were: i) planktonic/benthic ecosystem abundance, composition and structure, ii) primary productivity, (iii) the mapping of biodiversity, (iv) the expansion of non-indigenous species and fish population, iv) the physical damage and loss of habitats, v) biological disturbance: extraction of species, including non-target catches; (vi) food web. Looking at the synergic work performed on developing new assessment elements, it is obvious that these will be from now on a hallmark for the future projects dealing with MSFD, opening the gate to a high quality scientific research on Biodiversity in the future projects.

4. Conclusions/Discussion

One of the most complex MSFD Descriptor- Biodiversity was in particular very heterogeneous in terms of the assessment elements used by the SES countries. Discrepancies have been noted between EU and non-EU countries, especially at the level of the Black Sea. A good way for a better assessment is represented by the PERSEUS results, as an example of integrative approach of biological issues and the dynamic physical processes driving them.

5. Acknowledgements

This work has been funded by the EC FP7 PERSEUS Project (Grant. Agr. 287600).

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Analyses of eutrophication, invasive ctenophores, anchovy spawning areas in the Southern Black Sea

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Abstract

A specialised study with emphasis on addressing MSFD descriptors is designed in the Southern Black Sea. By making use of experimental investigations this study aims to address 3 defined hot topics; eutrophication, invasive ctenophores, and anchovy spawning areas in the Southern Black Sea.
During the 2013-2014 cruises the level of eutrophication and distribution of phytoplankton, zooplankton and impact of gelatinous zooplankton is studied and changes in the phytoplankton composition are addressed with respect to decreased concentrations of certain micronutrients (such as silica and phosphorus). Temporal levels in the concentration of invasive ctenophores are updated. Current spawning areas are investigated by sampling eggs and larvae of anchovy during the peak spawning seasons. *Keywords: Black Sea, eutrophication, gelatinous, anchovy*

1. Introduction

Objectives of this study are addressed under three sections. First part of this study aims at: i) understanding the changes in the level of eutrophication and distribution of phytoplankton, zooplankton and impact of gelatinous zooplankton, ii) filling the gaps to address changes in the phytoplankton composition, assuming decreased concentrations of certain micronutrients (such as silica and phosphorus), iii) assessing pressures and processes that cause and regulate eutrophication and their impacts on the South Western Black Sea. Second part of this study aims at understanding: i) the current levels of invasive ctenophores and their impact on native zooplankton and on fish, and ii) invasive ctenophores’ effect on lower trophic web -microzooplankton, phytoplankton and nutrients contents. Third part of this study focuses on: i) defining where most abundant fish, anchovy, spawn, and ii) clarifying modern spawning areas by sampling eggs and larvae of anchovy during the peak spawning seasons.

2. Materials and methods

Observations are based on two Cruises were carried out in July 2013 and November 2014 in the South Western Black Sea.

3. Results

Long-term nutrient data suggest that with the current and future nutrient inputs from anthropogenic (human-induced) sources, the nutrient levels are hardly possible to return their levels in the 1950-1960’s. Moreover, DIN/PO4 and DIN/Si ratios in rain and rivers waters will differ from the old ratios due to damming of the major river waters and the increased atmospheric pollution (enrichment of DIN and bio-available dissolved organic nitrogen).
Highest biomass of gelatinous macroplankton, observed in the south-western Black Sea, can be attributed to Danube river effect. The biomass and abundance of *Mnemiopsis leidyi* were significantly higher in the eastern than in the western region. The higher abundance and biomass of *M. leidyi*

inshore waters compared to offshore indicates that reproduction occurs in the coastal areas, as they warm up earlier. Compared to previous studies (Mutlu (1992), Kideys /1996 and 1999) and Romanova (2001)) *M. leidyi* biomass is lowered in the south-eastern part of the Black Sea. Spatial distribution and composition of zooplankton was studied in the southern Black Sea at 46 stations in July 2013. In terms of fodder zooplankton highest abundance values were observed in the west and lowest in the middle. Another important finding was absence of *N. scintillans* in the eastern part in July 2013. There is more anchovy reproductive activity in the south compared to the past (Einarsson and Gürtürk, 1960; Niermann et al., 1994; Kıdeyş et al., 1999), as the number of eggs found in July 2013 is by far greater than for any of the surveys conducted previously. The difference is most striking in the mean number of larvae, which is almost 15 fold greater than the nearest number previously recorded.

4. Conclusions/Discussion

Results indicate that the reduced DIN inputs will reduce POM production and also DIN/P ratios of surface waters, leading to N-limited primary production, which can be forecasted by N-P-Si coupled ecosystem models under changing climate conditions and reduced human pressures.
Current levels of gelatinous organism compared with past results from Mutlu (1992), Kideys /1996 and 1999) and Romanova (2001), were similar for the mean biomass for *A. aurita* and *M. leidyi,* but *Pleurobrachia pileus* (a comb jelly) mean biomass is lower than the previous values.
The increased egg vitality shows that not only were more eggs spawned in the south, but also that survival rates of the eggs to larvae have improved over the last 2 decades. Anchovy eggs and larvae were found at every station sampled in 2013, whereas in the previous surveys, no planktonic anchovy were present at certain stations. This shows that the spawning site selection is not localized to specific areas but that the anchovy spawn over the entire basin.

5. Acknowledgements

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP)

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Small cyclopoid copepod *Oithona davisae* invasion into the Black Sea as a factor of the changes in zooplankton and ichthyoplankton in Crimean coastal waters

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Abstract
The changes in the zooplankton and ichthyoplankton communities of Sevastopol Bay caused by introduction and propagation of NIS cyclopoid copepod Oithona davisae introduced to the Black Sea in early 2000 were studied during 2002 -2014. Bray-Curtis similarity index reflected two well-defined periods 2002-2005 and 2006-2014 (before and after introduction of O.davisae). Increase of O.davisae abundance was followed by gradual increase of fish larvae abundance. Mean fish larvae total length increased significantly during 2006 - 2014 (in comparison with 2002-2005) explained by increased fullness of their guts with high share of nauplii and copepodid stages of O.davisae, especially of commercial fish species.
Keywords: invader, zooplankton / ichthyoplankton community modification

1. Introduction

Invasion and proliferation of NIS populations usually lead to significant changes in recipient ecosystems, and often resulted in negative economic consequences. Accidental introduction of NIS is recognized to be the most severe human impact of the Black Sea ecosystem as it was observed with invasive ctenophore *Mnemiopsis leidyi* in the Black Sea caused catastrophic changes in copepod community (Gubanova, 2002), and resulted in starvation of the fish at early stages of development (Tkach, 1998). The key aspect of our investigation was the study of modifications in the zooplankton and ichthyoplankton communities of Sevastopol Bay caused by invader, cyclopoid copepod *Oithona davisae.*

2. Materials and methods

Analysis was based on the regular long-term monitoring of the plankton community in Sevastopol Bay, Crimea, Northern Black Sea. Samples of mesozooplankton were collected during 2002-2014 twice a month by vertical hauls through the whole water column (from bottom to the sea surface) using a Juday plankton net (mesh size 150 µm), fixed with 4% formaldehyde solution. Zooplankton was processed by the methodology for zooplankton studies in the Black Sea (Michneva, Stefanova, 2013.). Ichthyoplankton was collected using a fish larva net Bogorov-Rass (mesh size 300 µm) fixed with 10% formalin. All larvae and juveniles were counted, identified, measured and weighed. The guts of larvae were dissected under a stereomicroscope; and food organisms were separated, examined under Nikon Eclipse inverted microscope at magnification 10 x 40, counted and identified to the lowest possible taxonomic category.

3.Results

Few specimens of *O. davisae* were first found in Sevastopol Bay in 2005. From 2006 *O. davisae* dominated the summer-autumn copepod community in Sevastopol area. From 2009 onwards *O. davisae* spread to coastal areas of Bulgaria and Romania (Altukhov et al., 2014; Michneva and Stefanova, 2013). Increase in number of NIS and expansion of the area of its habitat led to alterations in ecosystem structure and functioning. Cluster analysis using the Bray-Curtis similarity index (complete linkage) reflected two well-defined periods in zooplankton structure: 2002-2005 and 2006-2014, i.e. the periods before and after of the introduction of *O. davisae*. The average number of zooplankton in the first period (2002-2005) was 4571 ± 1295 ind. m^{-3}; in the second one (2006-2014) - 13809 ± 6589 ind. m^{-3}. During 2002-2005 the species of genus *Acartia* dominated (22-43% of total abundance of fodder zooplankton), during 2006-2014 *O. davisae* dominated (the dominance 52-70%). From 2006 onwards, following the increasing number of *O. davisae* the gradual increase in number of species and the total number of fish larvae was observed. By 2008 - 2009 the total number of fish larvae was comparable with the total number of fish larvae in 1960s - 1970s, before invasion of *M. leidyi*, mainly due to high number of fish larvae of summer spawning fish species. During 2002-2014 for the first time since 1990 the positive trend in the fish larvae number dynamics (R^2 = 0.3) was observed that corresponded to the positive trend in zooplankton population dynamics. The share of the larvae of fishes with pelagic eggs mainly commercial fish species (*Trachurus mediterranius ponticus* and *Mullus barbatus ponticus*) reached its highest level (44% of the total number of fish larvae) in 2014 first since 2002. Increase in the fodder zooplankton abundance resulted in a sharp increase of the mean fish larvae total length during the period 2006 - 2014 years compared to the period of 2002 – 2005: 5.3 ± 0.2 mm *versus* 3.6 ± 0.2 mm, respectively. After the increase of *O. davisae* abundance during 2006 -2014 significant increase in prey number per larvae gut was observed: in 2006 the average prey number in larvae guts was 2-3, while in 2014 it increased to 7-9. Nauplii and copepodid stages of *O. davisae* contributed significantly in gut contents of the early fish larvae of commercial species (up to 100% in *Mullus barbatus*) during abundance peak of *O. davisae* in 2014.

4. Conclusion

Positive type of NIS effect on plankton community of Sevastopol Bay (increase of total abundance of fodder zooplankton resulted in positive trends in abundance of fish larvae) can be expected further for other Black Sea coastal areas.

5. Acknowledgements

This work was supported by the projects PERSEUS (FP7-287600) and Russian Foundation for Basic Research (RFBR Grants № 14-45-01581).

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Hydrobiota of the Georgian Black Sea coastal zone

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Abstract
The aim of research is the following: identification of hydrochemical parameters, collection of phytoplankton, zooplankton, epifauna and benthic organisms, conservation, species identification, number and biomass determination, identification of dominant groups and species being essential for the state of ecosystems. In parallel with hydro-biological studies the hydrological and hydro-chemical indicators of sea water were determined. Hydrological parameters included pH, conductivity and salinity.
Keywords : Hydrobiota, coastal, ecosystem

1. Introduction

Studying of taxonomic composition, quantity, biomass and productivity of macroalgae gives a chance to make a conclusion on each waterpond condition. Studies on phytoplankton for its key role in water quality formation, on zooplankton for the assessment of the water ecological condition, and on epifauna for its activation of the biofiltration process of the coastal zone, were performed. Furthermore, and despite of its Mediterranean origin the benthofauna of the Black Sea are 4-5 times less.

2. Materials and methods

In the Georgian Black Sea coastal zone (Gonio, Kobuleti, Poti) seasonal surveys have been carried out. pH, salinity, conductivity and dissolved oxygen were measured with the electrometric method. For the determination of chlorophyll *a* water was filtered using All-Glass Vacuum Filter Holder. The samples of Phytoplankton were collected instrumentally by using Bathometer (V=1,00 L). Collection of epifauna was carried out by the Frame Method (with an area 324 m^2). Benthos samples was collected by Van Veen Grab.

3. Results

During the research period, the absolute salinity of coastal zone water at the water surface varied between 11.49 (Kobuleti aquatory) – 17.65 ‰ (Poti aquatory). At the depth of 20 meters the content of salinity varied between 16.12 ‰ (Poti aquatory) – 17.79 ‰ (Gonio aquatory). During the observations on hydrological station in Gonio, the pH values for the surface layer and at a depth of 20 meters were 8.3-8.4 and 8.4-8.5 respectively; on station Kobuleti – 8.3-8.5 and 8.3-8.6 respectively; and on station Poti – 8.2-8.6 and 8.3-8.7 respectively. Furthermore, suspended solids in the surface layer varied between 1.2-4.1mg/L and the reduction of this indicator was observed at all hydrological stations. Additionally, the number of suspended solids at a depth of 20m varied between 0.6-2.5 mg/L. According to the collected results, the water masses both at sea surface, as well as at the depths of 20m, are well aired; this is confirmed by the high content of dissolved oxygen. The oxygen concentration at surface layer varied between 7.70-10.68 mg/L (100-110 saturation %). With increasing depth, the insignificant reduction in the dissolved oxygen concentration in the water was observed (96-107saturation %). In surface layer waters chlorophyll α varied from 8.8 to 65.7 μg/L. The highest content of chlorophyll *a* was observed at spring and summer seasons, having an average

of 42.0-65.7 µg/L. In autumn, the vertical distribution of chlorophyll *a* had being normal for the period and its concentration decreased with increasing depth.
There were 91 species and subspecies observed in the samples of four seasons throughout the studied years. 37 species of them were Diatoms, 30–Dinophyta, 11–Chromophyta, 6-Chlorophyta and 7–Cyanophyta. The study of zooplankton in the Georgian Black Sea coast shows that: at a depth of 5m the biomass of zooplankton is higher in Gonio region, and at a depth of 20m isobath the biomass of zooplankton is higher in Poti region (Fig.1).
The quantity of zooplankton at a depth of 5m is higher in Poti region and at a depth of 20m the quantity of zooplankton species is higher in Gonio studied region (Fig.1).

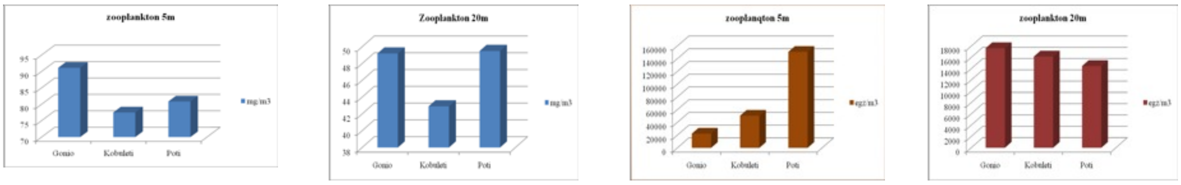

Fig. 1 *Zooplankton Biomass (mg/m^3) and Quantity (egz/m^3) of the Georgian Shelf Zone (Gonio, Kobuleti, Poti)*
.
There were 46 species of zoobentos identified in the bottom samples. They are presented by groups of Mollusks with 18 species being in the 39% of zoobenthic species composition. Polychaeta is represented by13 species, Crustacea - is represented by 10 species and is 28 and 21 % respectively. The diversity of Polycheta, Mollusks and Crustaceans basic groups distributed at a depth of 20m isobaths of the Georgian shelf, together with their seasonal dynamic, quantity and biomass, does not vary significantly. Dominant species of this bottom settlement are: *N. cirrosa*, from mollusca *Ch.gallina* and *C. cornea*, arthropods *C.pestai* and *B.improvisus* (Fig.2).

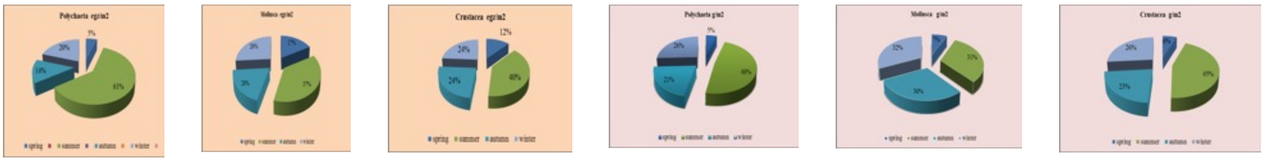

Fig 2. *Quantity (egz/m^2) and Biomass (g/m^2) of the Georgian Shelf Zone (Gonio, Kobuleti, Poti) of the main Zoobentic Groups.*

4. Conclusions

Based on the results collected during the study of phytoplankton, we can conclude that the quantity of species from dominant Phytoplankton groups is higher during the autumn season in comparison with the other seasons.The Kobuleti region reveals the greater amount of dominant species observed.The smallest number of species were fixed in Gonio research station. Dominant species mostly represent the Diatom groups, as follow: *Skeletonema coststum*, *Leptocylindrus minimus*, *Chaetoceros lorenzianus*, *Ch.affinis*, *Thalassionema nitzschioides*. Based on Epifauna sampling, we can conclude that the main groups that composed the epifauna are: Mollusca, Arthropoda, Annelides, Platyhelminthes, Sarcodina, Tentaculata. The most abundant species were Mollusca (Bivalvias), Arthropoda (Cructaceans) and Annelides (Popychaeta). The diversity of Polychaeta, Mollusks and Crustaceans basic groups distributed at a depth of 20m isobaths of the Georgian shelf, also their seasonal dynamics, quantity and biomass is quite similar. Dominant species of this bottom settlement are: *N. cirrosa*, from mollsca *Ch.gallina* and *C. cornea*, arthropods *C.pestai* and *B.improvisus*.

5. Acknowledgements

This research has been supported by the project: “Policy-oriented marine Environmental Research in the Southern EUropean Seas” (PERSEUS, EC 7th FP).

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Progress in understanding scyphomedusae outbreaks in the Mediterranean Sea: distribution and phenology

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Abstract

The increasing pressure from anthropogenic disturbances that are currently disrupting the natural balance of Mediterranean marine ecosystems may lead to more frequent and more pronounced jellyfish outbreaks. High jellyfish abundances that occur in the Mediterranean Sea have negative consequences for human welfare. It is therefore necessary to identify the species that have the highest potential to form harmful blooms and locate the most sensitive areas for such outbreak events. To do this throughout the Mediterranean Basin, we propose that a continuous monitoring program to collect both presence/absence and abundance data on different blooming species should be initiated.

Keywords: jellyfish monitoring, Aurelia aurita, Pelagia noctiluca, Rhizostoma pulmo, Rhopilema nomadica

1. Introduction

High jellyfish abundances that occur in the Mediterranean Sea have negative consequences for tourism, fisheries and other human interests (Bernard et al., 2011; Nastav et al., 2013; Palmieri et al., 2014). Since the Mediterranean Sea is sensitive to the combined effects of anthropogenic disturbances, as pressures in this region increase, it may be more conducive to enhanced jellyfish outbreaks (Purcell, 2012). In this study, we address broadly the following 3 points:1) described the distributions of four scyphomedusa species (*Aurelia aurita* s.l., *Pelagia noctiluca*, *Rhizostoma pulmo* and *Rhopilema nomadica*); 2) explored species specific phenology which, in turn, would allow us to conclude whether a degree of intra-basin synchronicity exists among such blooming events, (3) evaluated the results of an one-year visual census in an effort to establish a more reliable monitoring approach than other ongoing methods.

2. Materials and methods

Distribution and phenology of Scyphomedusae in the Mediterranean Sea were determined from published data combined with our own observations/monitoring, fishery and regional agency monitorings and from evaluated news reports and citizen science applications. Visual censuses of jellyfish abundance were carried out weekly along three shoreline transects and bi-monthly/monthly along an offshore transect in the Gulf of Trieste, the northern Adriatic Sea (nAd). Visual counting was performed from the shore by walking along the same track of fixed distance in calm weather at the time of the predicted high tide. An observer identified and counted jellyfish along the offshore transect using the same procedure as for coastal transects.

3. Results and Discussion

Distribution and phenology of selected Scyphomedusae. Our results revealed intra- and inter-species variations in phenology across the basins of the Mediterranean Sea. The intra-species variation detected for *Aurelia* and *R. pulmo* medusae populations occur mostly in the enclosed or semi enclosed areas, such as marine lakes and lagoons, possibly due to the adaptations to local environmental conditions. In contrast, *P. noctiluca* may be present throughout the year across the Mediterranean Sea, even in the nAd where it is a non–resident species. Nevertheless, timing of the reproduction period of *P. noctiluca* seems to differ locally; in the Central Mediterranean Sea it spawns over the December-February period, while in the nAd the reproduction occurs throughout the year (Rottini–Sandrini et al., 1983-84). It is noteworthy that *Aurelia* sp. and *P. noctiluca* rarely occur in the eastern Mediterranean Sea.

Coastal visual count of jellyfish. The results of the visual count differ between transects. The offshore count gave higher medusae abundancesas well as higher frequency of observations than any onshore counts.

4. Conclusions

Two main conclusions emerge from this study: 1) the temporal dynamics of scyphozoan populations across the Mediterranean Sea are not synchronized. 2) The coastal visual count method revealed the occurrence of medusae on a monthly basis; however, it cannot provide sufficient information to construct a semi-quantitative dataset. Therefore it is necessary to establish a better means of monitoring both jellyfish presence/absence and abundances, possibly using an approach similar to fishery monitoring, such as MEDITS and MEDIAS, but restricted to Scyphomedusae, to be included in the MSFD monitoring program.

5. Acknowledgements

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Effect of invasive ctenophores *Mnemiopsis leidyi* and *Beroe ovata* on microplankton communities of the Black Sea

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Abstract

The goal of the present study was to investigate the potential impact of excretion and mucus released by the ctenophores M. leidyi and B. ovata on the low trophic levels of the Black Sea ecosystem. Experiments were conducted in laboratory in aquaria. Water and ctenophores were collected in Varna bay in August 2014. The experiments showed an evident effect of excretion and mucus release of both species on hydrochemical parameters of environment. Abundance and biomass of phytoplankton and bacterioplankton, as well as chlorophyll and primary production increased several times considerably changing functioning of lower trophic food-web.

Keywords: alien species, impact, experiments, Black Sea

1. Introduction

The invasive ctenophore, *Mnemiopsis leidyi* (A.Agassiz 1865) is considered among "the ecosystem engineer", which affected all levels of recipient ecosystem. Since entering the Black Sea in the early 1980s, it has expanded the geographic range in the last decades over Eurasian seas. *M.leidyi* reached high abundances in most productive Eurasian seas that caused cascading effects on most components of the ecosystem. After the arrival of *B. ovata* in 1997, the Black Sea ecosystem began to recover.

The goal of the present study was to investigate the potential impact of excretion and mucus released by the ctenophores *M. leidyi* and *B. ovata* on the low trophic levels of the Black Sea ecosystem: bacteria, authotrophic/heterotrophic flagellates, nano-micro phytoplankton and microzooplankton species composition and taxonomic structure, abundance and biomass, chlorophyll a and primary production.

2. Material and methods

Two types of experiments were conducted jointly by SIO- RAS and IO-BAS as part of PERSEUS WP1, WP2, WP-4 research program – lab aquaria and *in situ* mesocosms in the coastal area of Gelendzhik (2013) and Varna (2014).

The laboratory (aquaria) experiments were designed to analyse the effects of ctenophores on hydrochemical parameters of the environment (pH, O_2, nutrients - N, P, Si and their ratios) and the structural and functional traits of food web lower trophic ecosystem components: bacteria, authotrophic/heterotrophic flagellates, nano-micro phytoplankton and microzooplankton.

3. Results

Changes in the measured parameters occurred in all experimental treatments, however, the patterns varied among the different settings. Both ctenophores *Beroe ovata* and *Mnemiopsis leidyi* induced changes in the chemical properties of the water, but they were more pronounced in experiments with *B.ovata*. All these changes resulted in different shifts in nutrient ratios especially

for Si/N and Si/P.
The initial concentration of phytoplankton community was high. The average for 3 replicates abundance 1300000 ± 370000 cells/l and biomass 819 ± 217 mg/m^3. Phytoplankton was marked with high diversity of species represented from 15 taxonomic classes. Increase in abundance and biomass occurred in all treatments at the 2nd day in all treatments. Both *M.leidyi* and *B.ovata* stimulated phytoplankton growth.
Experiments showed increase in concentration of chlorophyll and primary production in aquaria with *M.leidyi* and even higher increase in aquaria with *B.ovata.*
Bacteria abundance also show trend for increase in aquaria with *M. leidyi* and it was much higher in aquaria with *B. ovata*. Autotrophic flagellates and heterotrophic flagellates demonstrated an increase on the 2nd day and dropped to the initial level on the 5th day of the experiment. The growth of Diatoms, Dinoflagellates and Euglenophytes also was stimulated by the two ctenophores. While diatoms and Euglenophytes proliferated to a similar level, Dinoflagellates outburst occurred in the B treatments.

4. Conclusions/Discussion

The experiments showed an evident effect of excretion and mucus release of *M. leidyi* and *B. ovata* on hydrochemical characteristic of environment. Under controlled laboratory conditions both species induced changes in chemical properties– pronounced increase of nutrients ($P0_4$ and NH_4) and a decrease of pH. Simultaneously the nutrients release was much higher in the aquaria with *B. ovata*. Both species considerably changed the ratio between nutrients preconditioning possible "stoichiometric modulations" over the growth of biotic components.
Phytoplankton abundance and biomass increased several times under impact of ctenophores. This increase was also detected in chlorophyll concentration and primary production. This impact was also well seen in total bacteria abundance. Effect was much more considerable in aquariums with *B. ovata*. Phytoplankton species composition also changed evidently. Dinoflagellates outburst was observed in the *B. ovata* experiments, most likely related to the amount of released mucus (about two times higher in the case of *B. ovata*), which might explain the higher intensity of processes and related changes compare to *M. leidyi* and control.
Plotting interactions promises a deeper understanding on the functioning of lower trophic food-web under the impact of ctenophores, which could be taken into consideration for further improvement of modelling in service of proper ecosystem management.

5. Acknowledgements

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

Invasion of *Halophila stipulacea* in the Mediterranean Sea: an introduced carbon reservoir

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Abstract
Organic carbon stock was quantified in sediments of the non-indigenous seagrass, Halophila stipulacea, and in sediments of the native Mediterranean seagrasses, Posidonia oceanica and Cymodocea nodosa, as well as in adjacent unvegetated sediments at three sites of Crete, Greece. C_{org} stock was similar between H. stipulacea and P. oceanica at all sites, despite the huge size difference between species. This study shows for the first time that carbon storage, a key ecosystem service, is not negatively affected by the invasion of H. stipulacea.
Keywords: blue carbon, seagrass, macrophyte, climate change

1. Introduction

Carbon storage in underlying seagrass sediments is a key process in seagrass meadows (Fourqurean et al. 2012). The seagrass *Halophila stipulacea* (Forsskål) Ascherson 1867, native to the Indian Ocean and the Red Sea, has entered the Mediterranean Sea, where it is currently considered invasive (Galil 2008). Here, we aim at quantifying the carbon storage in *H. stipulacea* sediments, compared to that in the native seagrasses *Posidonia oceanica* and *Cymodocea nodosa*, and adjacent unvegetated sediments.

2. Materials and methods

The study was conducted in June-September 2011at three sites of Crete Island (Greece). Temperature range was 20-25 ^{o}C and depth 5-21 m. Sandy sediments characterized the sites, while disturbance by humans varied from low to moderate. Sediment cores were collected by hand from each site and habitat for the determination of dry bulk density and concentration of organic carbon (C_{org}) at the top 20 cm of sediment surface.

3.Results

C_{org} stock was significantly (p-value < 0.05) higher in *H. stipulacea* sediments than in *C. nodosa* from Sitia and Souda and unvegetated ones in Souda, while it did not differ from that of *P. oceanica* sediment at any site (Fig. 1).

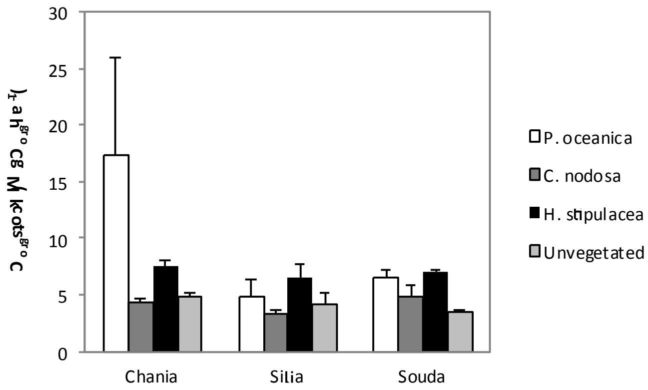

Fig.1 *Stock of organic carbon in the top 20 cm at each habitat and site*

4. Conclusions/Discussion

C_{org} stocks of *H. stipulacea* and *P. oceanica* were similar at all sites, despite the large difference in their shoot size. A similar pattern was observed for the two sibling species *H. ovalis* and *P. australis* in Australia (Lavery et al. 2013). The relatively high C_{org} stock of *H. stipulacea* implies that the species contributes in the increase of carbon storage in the Eastern Mediterranean. This study is the first to show that carbon storage, a key ecosystem service, is not negatively affected by the invasion of *H. stipulacea*. However, as the expected temperature increase may favor the further expansion of *H. stipulacea*, given the tropical/ subtropical origin of the species, further studies on the possible implications of the competition with the native seagrasses *P. oceanica* and *C. nodosa,* are necessary.

5. Acknowledgements

We thank Ioulios Glabedakis, Panayotis Vavilis and Thanos Dailianis for assistance with sampling. The study was funded by the EU FP7 project PERSEUS (Grant Agreement No. 287600).

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Habitat mapping with emphasis on sea grass meadows in the area of Sidi Rais (Tunisia)

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Abstract
In the framework of the EU-funded PERSEUS project (subtask 2.3.2a), we studied the distribution and evolution of the Posidonia oceanica and Cymodocea nodosa meadows through previous studies in the area of Sidi Rais, dedicated on-field observations and satellite high-resolution imagery. It appears that there is a regression of those seagrass meadows due to direct and indirect human activities in the area.
Keywords: Gulf of Tunis, Impact, Human activities, Posidonia oceanica, Cymodocea nodosa.

1. Introduction

In order to achieve the Good Environmental Status in a given area, it is first necessary to identify threats on marine ecosystems. In this work, the changes induced by anthropogenic pressures on the benthic ecosystem features to determine the level of impact caused by different threats were studied and attempted to be understood. In the study area (Sidi Raïs) two seagrass species were chosen: *Posidonia oceanica* and *Cymodocea nodosa* which are considered as hot spot indicators of balanced ecosystems.

2. Methods

First, existing data were gathered in order to have an idea on the distribution and evolution of the *Posidonia oceanica* meadows through previous studies. This work is based on four previous studies focusing on seagrass in the same area. These studies are: Ben Alaya (1972), Bouker (1998), El Asmi (2003) and Hachani (2013).
However, there are not many findings which studied the habitat mapping of *Cymodocea nodosa* meadow. Then, during 2013, a video survey was carried out in the same area, in order to observe changes in the habitat distribution pattern and additionally processed a high resolution satellite image in the visible spectrum (WorldView-2).

3. Results

The study area is divided to 3 different sectors which present three biocenosis types:
- The sector 1 (South-west of the pontoon):
This sector covers an area of 66 ha and is characterized by the presence of two rivers which can have an impact on the seagrass.
Cymodocea nodosa meadow presents the most important seaward extension, which reaches 245 m at the point (637352.62 m E; 4070082.87 m N) and presents the most important surface with 12 ha.
- The sector 2 (around the pontoon):
This part covers an area of 37.05 ha. The meadow is strongly subjected to the impact of human activities and especially to the moorings activities (anchors, waste discharges). There is a very

abundant coverage of *C.nodosa* and *Caulerpa racemosa*. The reef is also interrupted by inter-mattresses channels, which are individualized locally new colonies of *P. oceanica*.

- The sector 3 (North-East of the pontoon):
It is separated from the previous part by a rock band. This part covers an area of 43.29 ha. It is characterized by the presence of a cliff along the coast and boulders located a few meters from the shore. The *Cymodocea nodosa* meadow covers the smallest area with 6.67 ha.

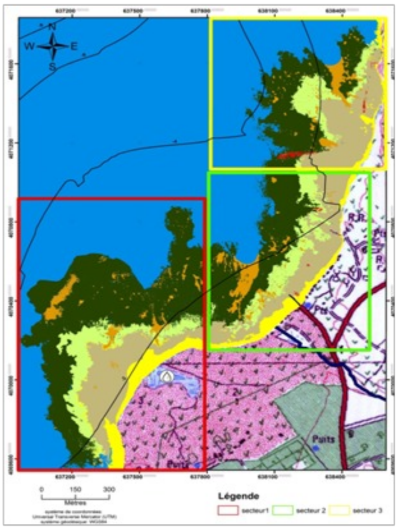

Fig.1The three sectors of the study

4. Conclusions

The *Cymodocea nodosa* is abundant near the coastline but it is in regression comparing the two studies (34688 m² in 1998 and 23044 m² in 2003). Concerning the *Posidonia oceanica* an evolution of the distribution was noted from 58410 m² in 1998 to 80511 m² in 2003 but a regression of the barrier reef from 43202 m² to 35330 m².

The comparison between the two documents (El Asmi (2003) and Hachani (2013)) shows that the seagrass in this study area are in regression (*Cymodocea nodosa*, the *Posidonia oceanica* and the barrier reef).

The Seagrass of this area are threatened by several pressures such as fishing activity, discharges of wadis and the introduction of competitive and invasive species which is considered as an indirect impact of human pressures.

5. Acknowledgements

We acknowledge the EU-funded PERSEUS project for supporting this work (Grant Agreement No. 287600).

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Ecological-Physiological Condition Indices of Mass Species Heterotrophic Components in the Black Sea Pelagic Ecosystem

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Abstract.
The bioenergetics condition of the mass components in the unstable Black Sea pelagic ecosystem was investigated and a hypothesis concerning their probable trends due to food supply and temperature possible changes during short (2-3 years) and long-term periods was proposed.
Keywords: Bioenergetics, jellyfish, planktivorous fish, food supply, temperature

1.Introduction.

Long-term investigations during 60s – 90s of XX century and first 15 years of XXI century the mass species bioenergetics in the Black Sea pelagic ecosystem (energy utilization for metabolism, feeding, propagation and growth rates as well as production, fat reserve accumulation) allowed to reveal the effect of significant environmental factors (first of all, food supply and temperature) on their condition. This gave possibility to make prediction about changes in that ones during near years and more long perspective.

2.Materials and methods.

The study was carried out in the North Black Sea on almost all trophic levels of pelagic ecosystem: copepods *Calanus euxinus* and others, medusae *Aurelia aurita* and alien ctenophores *Mnemiopsis leidyi* and *Beroe ovata*, pelagic fish *Sprattus sprattus phalericus* and subspecies of the European anchovy – the Black Sea *Engraulis encrasicolus ponticus* and the Azov Sea *E. e .maeoticus.* We studied their condition indices: the dynamics of abundance and biomass, the elements of their physiology (energy expenditures for metabolism, feeding, growth and production rates, the level of lipid accumulation as an indicator of well-being of the species, [Svetlichny and Hubareva, 2014, Anninsky et al., 2013, Finenko et al., 2013, Loret et al., 2014]. The standard methods of analyses were used. The relationships between the parameters studied and the main ecological factors (eutrophication, temperature, food supply, inter- species competition) were revealed.

3. Results and discussion.

It was shown that during the 1970-1980-s drastic biogenic increase in rich river inflow, first of all in Danube (resulting in phytoplankton bloom and subsequent abrupt rise in mesozooplankton number – fodder base of *Engraulis* and *Sprattus*) became a dominant factor for significant increase of fish stock [Lloret et al., 2014]. At that time pelagic fish biomass increased from 1000 to 3000 kt. At the end of the 1980-s – the early 1990-s the eutrophication brought to the favorite conditions for invasion and dramatic increase in *M. leidyi* abundance. It sharply decreased the fish fodder base and their stock. In the 90-s the number of *M. leidyi* reduced sharply due to new ctenophore *B. ovata* introduction which fed on *M.leidyi.* Pelagic fish stock restored up to 1500-2000 kt. It is known that in the beginning of the XXI century the temperature of the Black Sea surface layer increased by 2 ^{0}C due to global warming. It became the main factor regulating the condition of warm-water *E. encrasicolus ponticus* and cold-water *S. sprattus phalericus.* [Lloret et al., 2014]. The fat content in anchovy increased from

10 to 15 % of body mass. In contrast, fat content in sprat body fall from 10 to 5-6 %. The condition of sprat became worse due to a decrease in number of copepod *C. euxinus* in fish food [Yuneva et al., in press].

4. Conclusion.

The data obtained allow predicting of the condition of *E. encrasicolus ponticus* and *S. sprattus phalericus* populations and mass components of meso- and macroplankton for nearest future. Higher temperature will decrease the role of *M. leidyi* and *A. aurita* in food competition and anchovy food supply, spawning conditions and survival of juveniles and adults should be increased [Finenko et al., 2013, Anninsky et al., 2013]. If temperature continues to increase without reaching critical values for the Black Sea warm-water zooplankton and fish, the condition of these organisms will be better. In the case of global warming arrest (when the temperature is high enough), the condition of warm-water fish (including anchovy) will be stable.

5. Acknowledgements

This work was supported by the projects PERSEUS (FP7-287600).

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Ecological state of seagrass dominated habitats along the Bulgarian Black Sea coast

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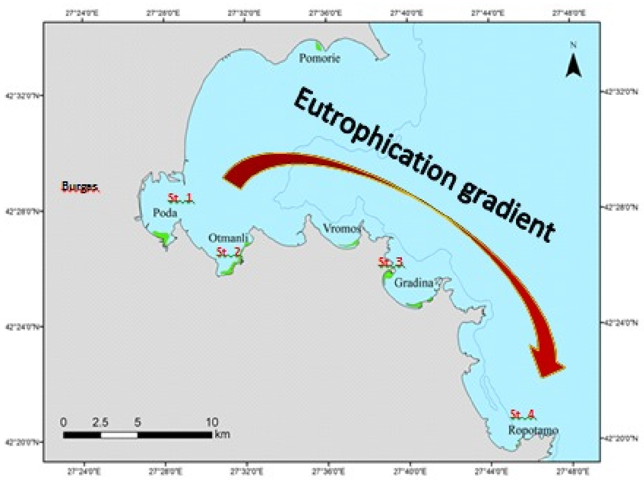
Abstract
This work aims to map the recent patterns of seagrass meadows distribution along the Bulgarian Black sea coast, to evaluate their ecological state according to WFD concept and to consider further data integration into GEnS determination according to MSFD criteria. Mapping was done according to the rules of Habitat Directive and the concept of FCS, while ecological status was assessed by using macrozoobenthos and a newly developed pollution index based on Z. noltei metrics (ZonPI) as biological quality elements. Data showed good agreement with the potential anthropogenic impact in the area.
Keywords: Seagrass habitats, Zostera spp., ecological status, HD, WFD, MSFD

1.Introduction

WFD provides a framework for the ecological state assessment of coastal water bodies but looks limited by the “*one out all out”* approach. As a consequence, except in cases with really severe impact in the shallow (up to 10m) coastal zones, biological quality elements (BQE) originating from those zones are not determinant for the final ecological state assessment. Commonly, the state of macrozoobenthos in bare sediments (at depth of 30-50m) prevails in the final status assessment.
In the present study the ecological status of shallow coastal sediments was evaluated based on macrozoobenthos and the angiosperm *Z. noltei* as BQE in seagrass dominated habitats.

2. Materials and methods

Four seagrass meadows were mapped and ground-truthed. *Zostera spp.* vegetated sediments were sampled in 2013 and 2014 (Fig. 1).



Meadow	Size in ha
St. 1- Poda	45.45
St. 2- Otmanli	17.94
St. 3- Gradina	22.73
St. 4- Ropotamo	2.27

Fig. 1: *Mapped meadows, sizes and sampling sites.*

Sampling was done at depth of 3.5-4m in the period end of June- beginning of July. For macrozoobenthos determination five sediment cores (i.d. 10cm, 20cm in height) were collected via SCUBA diving. Seagrasses were collected in five replicates with a cutting core device (31.5 cm in diameter).
AMBI (Borja et al., 2003) and BENTIX (Simboura and Zenetos, A., 2002) indices were applied for assessing the state of macrozoobenthos, while seagrasses state was assessed by applying a newly developed pollution index based on *Z. noltei* metrics (ZonPI).

3. Results

All tested indices vary slightly in their ecological state assessments but well reflect the impact of the pressures gradient, presented as LUSI scores (Table 1).

Table 1. *Performance of the indices tested.*

Station	EQR			LUSI-3000 at catchments	
	AMBI	Bentix	ZonPI	water bodies	local
Year 2013					
St 1	0.36	0.40	0.31	3.75	4.75
St 2	0.43	0.46	0.66		3.75
St 3	0.80	0.81	0.65	2.50	2.50
St 4	0.40	0.45	0.49	2.75	3.75
Year 2014					
St 1	0.76	0.72	0.37	3.75	4.75
St 2	0.59	0.60	0.64		3.75
St 3	0.77	0.70	0.76	2.50	2.50

4. Conclusions/Discussion

Good agreement between AMBI, BENTIX, ZonPI and LUSI was found. In general, LUSI calculated at the level of local catchment area gives more accurate assessment of pressures distribution. Station 3 (Gradina) is the least impacted station in the area and is used as the referent one. Data provide room for further indices integration for GEnS determination.

5. Acknowledgements

This research was carried out under the financial support of the EU FP7 PERSEUS project

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The Black Sea Region – a system of changing systems: Case study – Romanian shelf

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Abstract

The paper aims to bring arguments in favor of approaching from a new perspective the issue of valuing ecosystem services by making use of socio-economic instruments. Due to an inadequate understanding of the relationship between natural and socio-economic systems, the ecosystem of the Black Sea has been undertaken through a lot of negative changes, with its capacity of resilience decreasing. The paper highlights the results of PERSEUS assessment according to MSFD methodological approach to socio-economic evaluation.

Keywords: MSFD, natural system, socio-economic system.

1. Introduction

The Black Sea Region (BSR) comprises the Black Sea Basin as a source of emerging functions, services and resources supporting the human-social-economic community around it: the core Black Sea Basin is limited by its geographical frontiers; the socio-economic system around the core system is without frontiers. Both natural and socio-economic Black Sea systems change.

Main characteristics of BSR comparing with other SES:

Natural system: genetically - an annex of the Mediterranean Sea; meromictic sea vertically stratified and horizontally presenting gradients: euxinic sea; moderate-low diversity, ready to accept newcomers; eutrophic-estuarine sea; high biological productivity.

Socio-economic system: high social diversity and active geo-political region; high economic diversity (oil and gases, fisheries, tourism, naval transport, submarine pipelines etc.); high contrasts system; transition - fluctuation – conflicts.

The most peculiar ecological aspects of the Romanian shelf are: strong influence of the Danube River discharge and the occurrence of gradients (salinity, temperature etc.), impoverishment of benthic and fish populations, diminishing biodiversity including fisheries collapse.

The overall aim of this paper is to understand and quantify the resources and services provided by ecosystems, their vulnerability and resilience.

2. Materials and methods

The results obtained in the EU FP7 Project PERSEUS by the Romanian team are based on analysis of the reports submitted by the MSs, on the initial assessment and GES assessment in accordance with MSFD regulations.

3. Results

The analysis of the reports concerning the healthy state of the ecosystem at the Romanian Black Sea sector reveals strong discrepancies between what we know about the socio-economic system and the information on the natural system. However, our knowledge of the two systems helps us understand and quantify the resources and services provided by ecosystems and draws attention to their vulnerability and resilience. In addition it helps us explore their pros and cons in practical contexts for assessing management interventions in marine and coastal environments. Although an uncertainty estimate is an integral part of a measurement result, in the many analyzed reports of the MSs from SESs in the framework of PERSEUS Project, the main conclusion is that uncertainty measurement is generally ignored. Consequently, estimating uncertainty is a fundamental and necessary exercise in any kind of measuring activity.

4. Conclusions/Discussion

There are aims for the proper monitoring in BSR: • To identify and quantify the effects of anthropogenic discharges/activities in certain marine basins or sectors, in the context of the natural variations in the system; • To identify and quantify the changes in the environment as a result of regulatory actions; • To ensure the quality of preliminary studies and safety data in ecosystem management, including decisions in conformity with designed monitoring.

A key requirement of the MSFD (CEC, 2008) is that MSs work together to implement each stage of the Directive in a coherent and coordinated way, aiming comparability across Europe.
MSFD – successful programmatic directive: • Should be applied by all MSs and expanded into non-EU countries; • Provides support for sustainable development; • Prepares learning methodologies that must continuously upgrade; • Helps create a mood for environmental protection and adaptive management of resources under global changes, including climate change; • Develops international cooperation and scientific collaboration.

5. Acknowledgements

This work has been funded by the EC FP7 PERSEUS Project (Grant. Agr. 287600).

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Dynamics of size, age and sex structure of *Rapana venosa* Population near Anapa Bay-Bar, the Black Sea

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Abstract

An observation of R. venosa population structure was carried out on two sites of Anapa bay-bar in the period from 2010 to 2015. The modal size of R. venosa was 40-60 mm; the age varied from 1 to 14 years; number of males in each sample was 1.5-5 times more than females. The less size and weight indices of females may be caused by their higher energy losses for reproduction.
Keywords: rapa whelk, age-size structure, Black Sea

1. Introduction

More than 60 years ago, the Asian whelk *Rapana venosa* (Valenciennes, 1846) (Gastropoda: Neogastropoda: Muricidae) successfully settled down in the Black Sea, resulting as a dominant species in the benthic ecosystems and demonstrating a wide spectrum of morphological modifications and feeding behaviour. Despite a huge role of introduced species in the functioning of isolated marine ecosystems, such as the Black Sea, the monitoring of Rapana population in the Russian sector was not conducted. In the framework of Anapa bay-bar monitoring, an observation of population structure of *R. venosa* was carried out in the period from 2010 to 2015.

2. Materials and methods

More than 560 specimens (5 samples) of rapa whelks were collected at 2-10 m depths in two sites on Anapa bay-bar, separated by a distance of about 10 km, Vityazevo and Blagoveschenskaya villages, in 2010, 2012, 2014 and 2015 (Table 1). The molluscs were measured using a caliper (shell height, SH) and weighed (total wet weight and wet weight of soft body without shell). Age was determined by counting spawning lines on the shell (Chukhchin, 1961), and sex by presence or absence of the penis. Weight index was calculated as the ratio of the wet weight to the total weight of a whelk.

***Table 1**. Characteristics of R.venosa samples collected in Anapa bay-bar coastal waters in 2010-2015*

Sampling site	Vityazevo, 06.2010	Vityazevo, 09.2010	Blagovesch., 06.2012	Blagovesch, 06.2014	Blagovesch, 06.2015
Sample size	112	160	96	76	110
Females average SH, mm	49.9±5.1	48.7±7.3	45.0±6.2	45.2±3.6	48.5±6.6
Males average SH, mm	57.0±10.4	53.7±6.3	50.6±5.4	52.7±5.2	58.1±6.3
Females modal ages, years	4	5-6	4	4	No modal age classes
Males modal ages, years	5	5-6	4-6	5	6-7 and 9-10
Weight index, females	34.4±3.6	29.8±2.9	28.6±3.0	27.1±4.1	32.2±4.2
Weight index, males	35.1±4.2	31.9±2.7	30.6±3.0	29.2±3.3	32.6±3.2
Females number, %	28	36	31	25	16
Males number, %	72	64	69	75	84

3. Results

Size structure of R. venosa Anapa bay-bar population did not change significantly during the observation period (Table 1, Fig. 1 left). Females' average sizes in all samples were less than males' average sizes. Comparison using t-test of males' and females' shell heights from Blagoveschenskaya showed significant differences in all samples ($p<0.000$). Average weight index of rapa whelks from Anapa bay-bar was 31.1% (Table 1). Average weight index of females tends to be slightly less than males': significant differences were found for samples collected in 2010 (September) (t-test: $p<0.000$), 2012 (t-test: $p=0.002$) and 2014 (t-test: $p=0.029$). The youngest whelks found on both sampling sites were less than 1 year old, while the oldest was 14 years old (Blagoveschenskaya). Contrary to size, age structure of different samples was subject to a greater variation (Fig. 1, right). The difference between males' and females' ages was not revealed (Kolmogorov-Smirnov test: $p>0.1$ in all cases). The number of females in all samples was 1.5-5 times less than males (Table 1). A proportion of females in Blagoveschenskaya reduced from 2012 to 2015, comprising 31%, 25% and 16% respectively. A smaller proportion of females was also found by us in other sites of the Russian Black Sea coast.

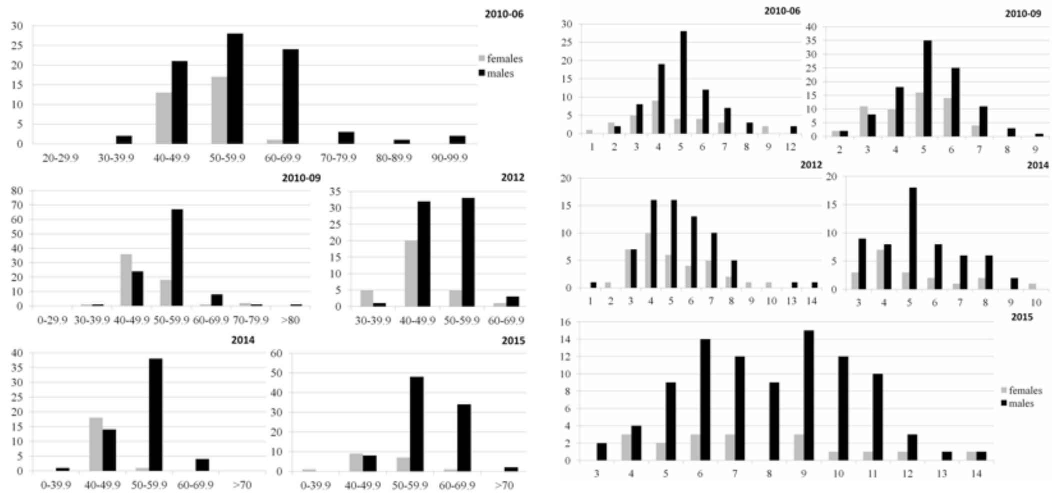

Fig. 1. *Size (to the left) and age (to the right) structure of Rapana venosa from Anapa bay-bar in 2010-2015. X-axis – shell heights/age, mm/years; Y-axis – number of observations. Sampling dates are indicated in the upper right corner of each histogram.*

4. Discussion

Published data for rapa whelks from the Kerch Strait, a neighbour region to Anapa bay-bar, report that modal shell height was 90-110 mm to the early 90-ies, 80-100 mm in 1990-1994, 55-85 mm in 1997-2000, and 50-90 mm in 2001-2006 (Yevchenko, 2010). Until 1997, the share of small whelks (41-50 mm) was not more than 1%, followed by 8% in 1998 and 23-41% in 2007-2008. In 2010-2015, the modal size of *R. venosa* from Anapa bay-bar decreased even more, resulting in 40-60 mm. The age structure within the modal size class was very heterogeneous ranging from 1 to 14 years. Probably, after reaching the age of sexual maturity, the size of the whelks does not significantly increase because of limited food resources and very low growth rate. Females had smaller average sizes and weight indices owing to higher energy losses for reproduction. An uneven sex distribution, with 1.5-5 times less females share, may be connected with worsened living conditions.

5. Acknowledgments

The study was supported by the Russian Scientific Foundation grant No. 14-17-00547.

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DNA barcodes of the Levantine basin fish species.

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Abstract

One hundred and twenty fish species from the Israel's Mediterranean coast were identified and quantified using the DNA barcoding tool. Totally DNA barcode of 280 fish specimens, (265 Actinopterygii and 15 Elasmobranchii) belonging to 75 native and 35 Lessepsian migratory species, were obtained using the mtDNA COI gene region. Distance summary, barcode gap analysis and discordance detection were carried out using the BOLD system. The most distant clade of all samples analyzed was the Elasmobranchii subclass, consisting of fifteen sample sequences clustered on a separate branch from the Actinopterygii.
Keywords: Mediterranean, fish, DNA barcode, phylogeography, invasive species.

1. Introduction

As biological invasions are now occurring at alarming rates (Galil, 2009), the increased introduction of alien and invasive species becomes an important driver for the changes that occur in the Mediterranean Sea biodiversity (Coll et al., 2010). The Levantine basin is a hotspot for biological invasion (Galil, 2009). Traditionally, morphology was a key factor for describing species. Moreover, damaged specimens and larvae can confuse even an experienced taxonomist. DNA barcoding, a standardized method for species identification (Hebert et al., 2003), would circumvent these difficulties. In this study, for the first time, the use of the DNA barcoding tool was evaluated in identifying fish species biodiversity near the Israeli Mediterranean coasts.

2. Materials and methods

Samples were collected in years 2011 and 2012 along the continental coast of Israel. The voucher specimens are stored in the Steinhardt National Natural History Museum and Research Center at Tel Aviv University. The cytochrome COI gene was amplified using universal primers. The data, of each specimen were submitted to the Barcode of Life Data System (BOLD, http://www.boldsystems.org), which is available within the project file 'Marine Biota of Israel-Mediterranean'. Distance, gap and haplotype, discordance analyses were done using BOLD system and DNAsp software (Rozas and Rozas, 1999)

3. Results

The COI sequences were obtained from 280 fish specimens (265 Actinopterygii and 15 Elasmobranchii) belonging to 110 species, 92 genera, 57 families and 18 orders. In total 176 haplotypes were observed, 121 of them belonging to the native fish species and 55 to the Lessepsian fish species. The most distant clade of all samples analyzed was the Elasmobranchii subclass, consisting of fifteen sample sequences clustered on a separate branch from the Actinopterygii. The evolutionary history and phylogeographic analysis of 110 fish species was inferred using the Neighbour joining and the Bayesian methods.

4. Conclusions/Discussion

Here COI barcodes were presented for 110 fish species that inhabit the Israeli Mediterranean costs, and compare the present study outcomes to the BOLD system database. The species assignments of the present study were generally straightforward, with species barcodes forming unambiguous monophyletic clusters.

5. Acknowledgements

This study was supported by PERSEUS-FP7 project and the Israeli Ministry of Infrastructure.

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Diet of Pelagic Fish in Zmiinyi Island Coastal Waters (Black Sea)

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Abstract
Diets of the anchovy, sand smelt, bluefish and horse mackerel, the main pelagic species in the Zmiinyi Island coastal waters have been described and analysed: The Index of Relative Importance, of food items these species of fish have been presented.
Keywords: ichthyofauna, trophic spectrum, The Index of Relative Importance.

1. Introduction

According to recent studies (Snigirov et al., 2012), large aggregations of bottom-dwelling and pelagic fish have been registered in the Zmiinyi Island coastal area. By now the species composition of fish community in the island coastal waters has been sufficiently studied. However the biological and ecological aspects of some fish species in the area remain understudied. At present these studies acquire special importance in view of MSFD implementation by the Black Sea countries. This has determined the aim of the present work – study the diet peculiarities of anchovy *Engraulis encrasicolus ponticus* (Alexandrov, 1927), sand smelt *Atherina pontica* (Eichwald, 1831), bluefish *Pomatomus saltatrix* (L., 1766) and horse mackerel *Trachurus mediteraneus ponticus* Aleev, 1956.

2. Materials and methods

The methodology of study are described in details in the paper (Snigirov et al., 2012) he most abundant pelagic species were selected in 2013-2014 to study fish diet in the Zmiinyi Island coastal area. Significance of food items in fish diet was calculated using the formulas: Index of Relative Importance (IRI) (Pinkas et al., 1971):

$$IRI\ (\%) = (N_i\% + P_i\%) \cdot F_i\%,$$

where N_i – quantity of *i* – item in fish diet, P_i – weight of *i* – item in fish diet, F_i – frequency of occurrence of *i* – food item in stomachs (guts) of fishes.

3. Results and discussion

The average overall length of the anchovy caught near the Zmiinyi Island in 2013-2014 was found to be 10.5-11.6 cm, and the weight 8.1-11.3 g. The highest intensity of anchovy feeding near the island was revealed in autumn 2014, while the lowest intensity was observed in winter period of 2013. The highest quantity of individuals (25%) with empty stomachs was found in winter 2013. In spring and autumn 2014 the share of individuals with empty stomachs were 7.3 and 14.3% respectively. The diet of anchovy comprised of organisms belonging to 15 taxa. The most significant were *Polychaeta* (IRI – 2579.4-3667.6), *Mysidacea* (IRI – 209.8-2600.2), *Amphipoda* (IRI – 102.1-698.6), *Rotatoria* (IRI – 102.5-486.2) and *Copepoda* (IRI – 3.8-835.8). Planktonic larvae of *Polychaeta* and molluscs were also found, though they were much less in number. Under shortage of zooplankton, anchovy have to feed on phytoplankton. The share of phytoplankton in the total weight of food boluses of the analysed individuals ranged from 3.8 to 78.0 %. Average values of total length of the sand smelt specimens were 7.6-8.8 cm, and the weight 3.1-4.9 g respectively. The diet of sand smelt comprised of food items of 17 taxa. *Polychaeta gen. sp.* (IRI – 1994.3-4045.4), *Mysidacea* (IRI – 101.5-858.4) and *Amphipoda* (IRI – 4.7-871.5) prevailed. Planktonic crustaceans played a significant role in the diet of this species. Mean total length values of males and females of horse mackerel in 2013 were recorded at 14.1±0.1 cm, and weight 25.7±0.9 g. In spring and autumn 2014 those values were length: 15.6±0.3 and 17.0±0.4 cm, and wight: 37.0±2.4 and 47.5±4.1 g respectively. It was established in the course of studies that the diet of horse mackerel comprised of organisms belonging to 16 taxa. In 2013 and 2014 *Polychaeta* (IRI – 2710.0-3295.7) and crustaceans *Amphipoda* (IRI – 1.4-2175.1) were a significant share of horse mackerel diet. In food boluses of big individuals the fry of horse mackerel was found, whose significance in the diet was also quite high (IRI – 295.9-492.1). Bluefish individuals whose average length was 18.7-19.7 cm, and weight 67.0-79.6 g dominated in the catches. The spectrum of their diet was represented by 8 food items. Fish (*En. encrasicholus, T. m. ponticus, S. s. phalericus* and some others*)* prevailed in the food boluses of the analysed specimens.

It is thus concluded that the main diet of horse mackerel and bluefish in the coastal waters of the island is fish. For anchovy and sand smelt, in autumn, when significant shoals accumulate near the island and under shortage of zooplankton (their main food) these fish species consume other organisms such as Amphipoda, Isopoda, Mysidacea and other crustaceans, as well as Polychaeta. In cases of shortage of food anchovy have to feed on phytoplankton. The share of phytoplankton in the total weight of food boluses of the analysed individuals made 3.8 to 78.0 %.

4. Acknowledgements

The work has been done in the framework of the international FP7 PERSEUS Project No. 287600 (2012-2014) and the National projects (2003-2014).

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Toxic Metals in Fish and Mollusks of the Zmiiniy Island Coastal Waters (North-Western part of the Black Sea) in 2012-2014

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Abstract

The results of Toxic Metals (TM) determination in fish and mollusc species for 2012-2014 in the north-western Black Sea (NWBS) have been presented. It has been shown that the soft tissue samples of molluscs and fish mass species collected in the coastal waters of the Zmiinyi Island periodically revealed high levels of certain TMs concentration (As, Cu, Zn, Ni, Fe, Mn) which was connected with the Danube discharge and the diet of concrete species.

Keywords: Black Sea, PERSEUS, Toxic Metals, biota

1. Introduction

Last years investigations of pollution in biota in NWBS were finalized (Jitar et al., 2014, Medinets et al., 2014a,b). The objective of our research in the framework of PERSEUS Project was to determine the levels of TMs in fish and molluscs to fill the gaps in evaluation of levels of contaminants and pollution effects.

2. Materials and methods

The results of studies of TMs accumulation in the mass species of fish and molluscs in the Zmiinyi Island coastal waters for the period 2012-2014 were presented. Mass species of molluscs as mussels *Mytilus galloprovincialis* Lamarck, 1819 and rapa whelk *Rapana venosa* (Valenciennes, 1846) and fish species as round goby *Neogobius melanostomus* (Pallas, 1814), common blenny *Parablennius sanguinolentus* (Pallas, 1814), grey wrasse *Symphodus cinereus* (Bonnatterre, 1788), sole *Pegusa lascaris* (Risso, 1810) and anchovy *Engraulis encrasicolus* (Linnaeus, 1758) were analysed for Cd, Cu, Hg, Pb, Zn, Co, Ni, Cr, Fe and Mn using methods (Medinets et al, 2014b, RSRM 8, 1985 and RSRM 11, 1984).

3. Results

The results presented reflect the TMs concentrations in the dominant demersal and bottom-dwelling species: round goby, common blenny and grey wrasse. It was shown that round goby as a typical mollusc-eating species accumulated TM contained in large quantities in tissues of mussels dwelling in the coastal waters of the island. For common blenny, which mostly feeds on macrophytes, maximal concentrations of copper, zinc and iron were registered in 2012. The concentration of TMs in grey wrasse and sole, which are feeding mainly on small benthic crustaceans, was significantly lower than in the mollusc-eating round goby. Concentrations of TMs in anchovy (pelagic migratory species) soft tissues were minimal. Analysis of average annual TMs concentration values in mussels during the period of studies revealed the highest level of pollution with TMs in 2012 when the impact of the Danube River discharge was major.

4. Conclusions/Discussion

Analysis of soft tissue samples of mass species of molluscs (mussel and rapa whelk) and fish (round goby, common blenny, grey wrasse, sole and anchovy) collected has revealed the periodically high TMs concentrations (As, Cu, Zn, Ni, Fe, and Mn) in the samples, The TMs average annual concentrations analysis in 2012-2014 has shown that maximal pollution levels for practically all the studied hydrobionts were observed in 2012 (the year of heavy precipitation and the highest discharge of the Danube River). During the low-water periods of 2013-2014 the levels of hydrobionts pollution with TMs decreased significantly. It was shown that the levels of TMs in fish species were depended from the diet of the concrete species.

5. Acknowledgements

The work has been done in the framework of the FP7 PERSEUS Project No. 287600 (2011-2015) and the National projects funded by the Ministry of Education and Science of Ukraine.

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Assessment of the contamination status of the Romanian Black Sea ecosystem during 2012 – 2014, within implementation of the European Marine Strategy Framework Directive (MSFD)

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Abstract
In this work, as assessment of the contramination status of the Romanian Black Sea, has been done for the period of 2012 to 2014.
Keywords: marine pollution, heavy metals, organic pollutants, GES

1. Introduction

The Black Sea is affected by important natural and anthropogenic pressures, resulted from the growth of coastal populations, the exploitation of marine resources, the development of shipping, off-shore activities, tourism and industrialization. Establishing a relationship between pressures and environmental status is necessary in order to identify the main causes of any change. The knowledge of these relationships is essential for pertinent and efficient measures so as to achieve and maintain Good Environmental Status (GES) in marine ecosystems. The main objective is to investigate these relationships and link the pressures with the impacts in the marine environment, focusing on characteristics and peculiarities of the coastal Black Sea ecosystem. The assessment of Good Environmental Status (GES) under the Marine Strategy Framework Directive 2008/56/EC (MSFD) Descriptor 8 “Concentrations of contaminants are at levels not giving rise to pollution effects” for the Black Sea Romanian waters is based upon NIMRD pollution monitoring and assessment programme, providing a comprehensive approach.

2. Material and method

In the framework of the FP7 PERSEUS Project (Policy-oriented Marine Environmental Research for the Southern European Seas), new data (2012-2014) on a wide range of contaminants (heavy metals –HM, total petroleum hydrocarbons -TPHs, polycyclic aromatic hydrocarbons -PAHs, organochlorine pesticides -OCPs, polychlorinated biphenyls –PCBs) in seawater, sediments and biota from the Romanian Black Sea were obtained. Gradient of pollution was assessed along relevant monitoring transects, covering two PERSEUS study areas (16 – Danube mouths; 15 – Constanta). Two sampling campaigns/year were carried out by NIMRD (39 stations, grouped in 13 transects up to max. 30 nm distance from the shore, along Romanian Black Sea coast). Survey network was designed in a way to improve knowledge on the various influences upon the quality of the Romanian Black Sea waters, either Danube in the northern area (16), or various land-based sources in the southern one – Costanta (15). NIMRD monitoring database for contaminants in seawater, sediments and biota during 2006 – 2011 was compiled. It includes information on heavy metals (Cu, Cd, Pb, Ni, Cr) and organic pollutants (TPHs, PAHs, OCPs, PCBs) and data were used for assessing trends.

3. Results and discussions

Concentrations of heavy metals measured in seawater and sediments along the Romanian Black Sea coast were characterized by an increased spatial and temporal variability, under influence of

various natural and anthropogenic pressures. Overall, the majority of samples (percentile 75th of all data series) were situated below environmental quality standards for seawater (Directive 2013/39/EU) and sediments (ERL values – "Effects Range-Low" US EPA, 2002). Although occurred with a low frequency, higher variation ranges, even outliers and extreme values, were noticed especially in the area 16, under the influence of Danube river, and in specific locations from area 15, situated in the vicinity of big harbors (Constanta, Mangalia) or WWTP outlets. In comparison with 2006-2011 monitoring data, in the recent years heavy metals concentrations were found in general within the same variation ranges, in some cases with slightly decreasing trends. In biota (molluscs and fish) heavy metals presented high variability, showing inter-specific, but also intra-specific differences. Only a small percentage of molluscs and fish samples investigated during 2012-2014 didn't comply with the regulatory levels for Cd and Pb (EC Regulation 1881/2006).
Median values of the total petroleum hydrocarbons monitoring data, both in seawater and sediments from the Romanian sector of the Black Sea, indicates a moderate pollution, except few extreme values recorded in 2014 in the southern sector (area 15). In recent years, the average values of petroleum hydrocarbons from environmental components (seawater, sediments) continued a downward trend in the level of contamination compared to 2006-2009.
In 2014, the sediment quality assessment based on evaluation criteria, indicates GES for 46% of sediment samples from Romanian sector of the Black Sea, with a moderate level of pollution of polycyclic aromatic hydrocarbons (PAHs). For sediments with bad ecological status (BES) the dominant individual compound are naphtalene and phenanthrene. In recent years, the average values of polycyclic aromatic hydrocarbons in environmental components continued a decreasing trend in the level of contamination compared to 2006-2007. In 2012-2013, dominant compounds in fish and molluscs were represented also by naphthalene and phenanthrene, which are consistent with a composition profile following a petroleum exposure.
Median concentrations for most investigated organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in water and sediment was the limit of detection or a value close to limit of detection. Exception was the HCB and lindane, in water and PCB 28, PCB 52, in sediment, which often exceeded the proposed threshold values for defining good environmental status. Exceedances of the proposed threshold for defining GES were observed for some regulated POPs (lindane, heptachlor, PCB 28, PCB 52, PCB 118, PCB 101, PCB 138) both in fish and molluscs, in respect with Descriptor 8.

4. Conclusions

The assessment of organic pollutants and metals in study areas close to river mouths and coastal cities allowed the evaluation of their occurrence in ecosystem components, providing thus evidence of their impact under different natural and anthropogenic sources. Progresses in implementation of MSFD, namely Descriptor 8, in Romanian Black Sea waters and development of methodologies for assessing GES were achieved.

5. Acknowledgements

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Benthic fluxes of dissolved heavy metals in polluted sediments of the Adriatic Sea

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Abstract

This work presents some findings of PERSEUS and previous researches on the Adriatic Sea bottom sediments regarding the heavy metal pollution. The geochemical characterization of surficial sediments, the early diagenesis processes and the dissolved benthic fluxes have been investigate to evaluate heavy metal pollution in the studied area. Heavy metal concentrations in surface sediments, early diagenesis processes and dissolved benthic fluxes generally decrease from the Po River mouths southward as a consequence of dilution processes of Po River inputs with anomalies near the Italian coast for local continental inputs.

Keywords: sediment-water interface fluxes, early diagenesis, metal pollution.

1. Introduction

The aims of the work are to present the heavy metal and nutrient dissolved benthic fluxes and the early diagenesis processes in sediments affected by the Po River inputs along the western side of the Northern and Central Adriatic Sea (Fig. 1).

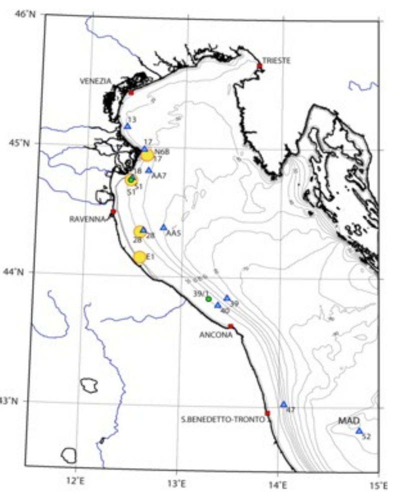

Fig.1 Benthic flux measurements and sampling stations in spring 2013 (yellow circles), autumn 2013 and 2014 (green circles) and previous researches (blue triangles).

2. Materials and methods

During the PERSEUS Project three cruises have been carried out in spring and autumn 2013 and autumn 2014 (Fig. 1). In each station dissolved benthic fluxes have been measured by benthic chamber deployments while early diagenesis has been studied by pore-waters extraction and analyses. The data collected in the PERSEUS Project have been compared with previous dissolved benthic flux measurements and early diagenesis studies. Previous studies have been used also to locate the stations along a sediment pollution gradient. The Perseus cruises allowed, for the first time, the *in situ* direct measurements of the dissolved benthic fluxes of some heavy metals (Co, Ni, Zn, Cu, Cd, Pb) other than of the main metals involved in the early diagenesis processes (Fe and Mn).

3. Results

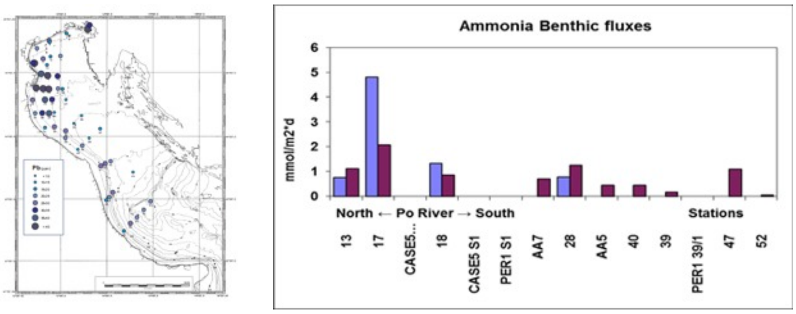

Fig.2 *a) Decreasing values from the Po River mouths to north and south of heavy metals (Pb) in surface sediments of the western Adriatic Sea. b) Decreasing values from the Po River mouths (stations 17 and 18) to north (station 13) and south (from station AA7 to 52) of nutrient benthic fluxes in the Adriatic Sea.*

Previous data (Spagnoli et al., 2014) and new PERSEUS studies indicate that:
1) a consistent decreasing southward and northward heavy metal pollution, deriving from the Po River inputs, is present in the surface pelitic sediments of the western Adriatic Sea (Fig. 2a); 2) different early diagenesis environments are present in the Northern and Central Adriatic Sea, they are comprised between two end members from the Po River Prodelta to the Mid Adriatic Depression (MAD) (Spagnoli et al., 2014). In front of the Po River sediments are characterized by high sedimentation rate and by high inputs of fresh marine organic matter, continental organic matter and Fe-oxyhydroxides. These inputs produce high concentrations of organic matter degradation products, strong anoxic environment in the pore waters and high dissolved benthic fluxes (Fig. 2b). In the MAD the diagenetic environments are characterized by low sedimentation rate and low inputs of reactive organic matter that produce low concentrations of pore-water organic matter degradation products with oxic conditions near the surface and weak benthic fluxes (Fig. 2b); 3) Fe and Mn dissolved benthic fluxes decrease from the Po River mouths southward and northward (Fig.3), this trend is attributed to the high Po River dissolved and particulate metal inputs that deposit in the surface sediments of the Po prodelta and of the high early diagenesis processes that take place near the Po River mouths (Spagnoli and Bergamini, 1997).

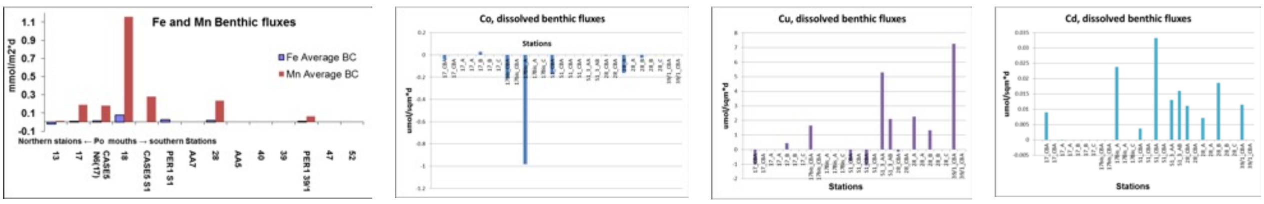

Fig.3 *Dissolved heavy metal benthic fluxes in the Adriatic Sea.*

Dissolved benthic fluxes measurements of other heavy metals (Co, Ni, Zn, Cu, Cd, Pb) indicate that some elements, such as Co and Pb (Fig. 3), are clearly adsorbed by the sediment that act, for these two elements as sink. Other elements, such as Cu (Fig. 3), don’t show a clear north–south trend suggesting that they are affected by local inputs, while other elements, such as Cd, indicate a southward decreasing trend suggesting a behaviour affected by the Po River inputs and Fe-Mn-oxyhydroxide cycle.

5. Acknowledgements

This research has been supported by the project: “Policy-oriented marine Environmental Research in the Southern EUropean Seas” (PERSEUS, EC 7th FP).

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Export of pollutants from a big Mediterranean city: modelling the dissolved and particulate transport of contaminants in the bay of Marseilles

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Abstract

Big cities of the Mediterranean area are a significant source of marine pollution. Metals and organics are brought to the sea through the sewage system and the surrounding catchments. A coupled hydrodynamic-hydrosedimentary model of the bay of Marseilles was developed to study the transport of contaminants, their dilution and potential accumulation area under several discharges, circulation patterns and weather conditions. Results show that a high proportion of contaminants discharged in the bay are exported offshore after a few days. Local impact is expected near outfalls for contaminants having an affinity for heavy particles.
*Keywords: coupled models, metals, Pcb, pollution, Gulf of Lion*s

1. Introduction

The Mediterranean Sea coastal area is facing an increase of its already high population density, especially in “mega cities”. Human activities result in a high anthropogenic pressure exerted on marine sensitive ecosystems. Pollutants discharged by cities to the sea affect the coastal environment before being transferred to the open sea where they can accumulate in secondary reservoirs. Some contaminants may bioaccumulate in marine organisms and biomagnify along marine food webs far away from their sources. The present study aimed to assess the fate of chemical contaminants originating from the city of Marseilles using a modelling approach.

2. Materials and methods

The hydrodynamic-hydrosedimentary MARS3D model (RHOMA configuration, Pairaud et al., 2011) was used to assess the chemicals dispersion or area of contaminants' accumulation in sediments in the bay of Marseilles. The contaminants affinity with organic matter was considered coupling the hydrodynamic model with the biogeochemical MASSILIA-ECO3M model. A focus was made on the fate of Pb and CB153, in order to take into account an organic and hydrophobic contaminant with an affinity for POC and DOC for the latter. The influence of hydrodynamics and of each input source was investigated. Finally, dilutions of total contaminants measured in the framework of the PERSEUS cruises off Marseilles in October 2014 were compared with dilutions obtained from the model for passive tracers.

3. Results and discussion

Floods were seen as a major contributor to contaminant input. Results show that a high proportion of contaminants discharged in the bay are exported offshore after a few days, especially under Mistral wind, and for those dissolved or sorbed on fine and light particles. Pb and CB153 sorbed on heavy particles had a tendency to accumulate close to the outlets. The dilutions measured during the PERSEUS cruise of 2014 for TCEP and CB153 matched the dilution of a conservative tracer given by the model (fig. 1), whereas that of Anthracen didn't. In addition to dilution, other factors are important to determine background concentrations in the coastal area, such as air-sea exchanges or the influence of rivers (e.g. River Rhone) at continental shelf scale

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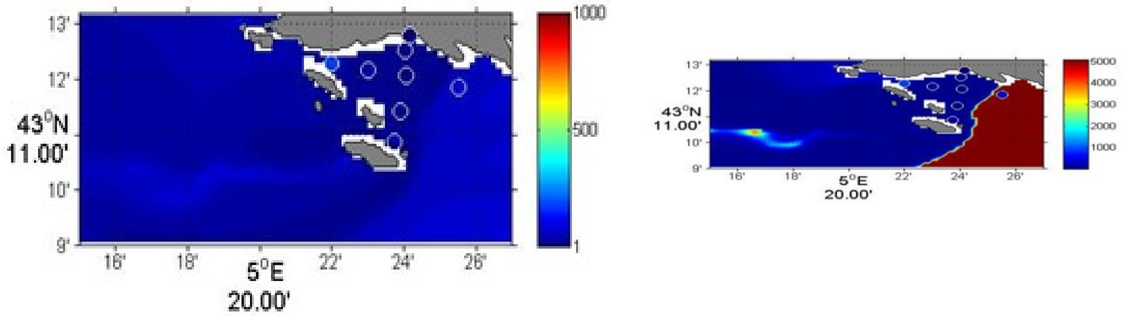

Fig.1 *Dilution of a conservative tracer (left) and of the light SPM (right) at the sea surface from the model, with circles standing for CB153 total dilution measured in the field for 1 October 2014 14:00.*

4. Conclusions

The bay of Marseilles appears mostly as a transit area for contaminant. Local impact is expected near outfalls where contaminants having an affinity for heavy particles can accumulate in sediments. A small proportion of contaminants may be transferred to the food chain via plankton exposure, especially during floods.

5. Acknowledgements

This work is part of the AERMC METROC, PNEC-EC2CO MASSILIA, MISTRALS-MERMEX and PERSEUS projects (EU-FP7 Grant N° 287600). Model runs used the Caparmor Brest facility.

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Combination of field data and modelling capabilities to support design of contaminants monitoring programs under the Marine Strategy Framework Directive

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Abstract

Organic chemical pollutants data was combined with hydrodynamic modelling experiments to study influence of coastal cities 'hot spots' in the marine environment. A multi-compound analytical method was developed and tested, providing evidence of legacy and emerging organic chemical contaminants inputs associated Marseille city. Sampling grid design is crucial for effective comparison of pollution among different coastal settings where different monitoring approaches may be required. The use of modelling capabilities facilitates monitoring program design by assessing a priori the behaviour and fate of pollutants under certain environmental conditions and hydrodynamics

Keywords: contaminants, organic chemicals, WFD, MSFD, coastal cities

1. Introduction

Contamination by chemical pollutants has been identified as an important issue by PERSEUS (Crise et al, 2015). At European level, the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC) require the development of monitoring programs for the assessment of chemical pollution. Existing inputs/sources associated with 'hot spots' and environmental conditions have to be considered when designing monitoring programs. Hydrodynamic modelling is an asset for establishment of appropriate monitoring grids.

2. Materials and methods

A sampling campaign (15 sampling stations, 20 litre surface water sample) was performed in the 'hot spot' coastal area of Marseille (30 Sept – 2 Oct, 2014). Hydrodynamics forecast was used to adjust the sampling grid to the existing local conditions during the sampling campaign. Environmental conditions included a rainfall event. This study involved developing and testing a new tool for coastal monitoring, the JRC multi-compound analysis method, where non-polar and polar organic compounds are analysed from one single sample. For analysis: isotope dilution and HRGC/HRMS techniques were applied for non-polar compounds; and UHPLC-MS/MS techniques for polar compounds.
A hydrodynamics, sediment transport and contaminant coupled model was set up to study the transport of dissolved and particulate contaminants released at sea from the city of Marseille, their dilution and accumulation area depending on the discharges, the weather and the hydrodynamics conditions. The model was operated both in operational mode prior to the cruises to provide forecasts for sampling design and in delayed-mode (post-cruise) to provide the environmental context and the plume patterns supporting thus also data interpretation.

3. Results

About 85 substances were identified in the study area including: PCBs, organochlorine pesticides, PAHs; organophosphate esters; and polar compounds such as corrosion inhibitors or pharmaceuticals. Decreasing concentration gradients were visible towards open waters in relation to three identified sources: Cortiou area, the river Huveaune and Marseille harbour. Combination of field data on contaminants and modelling experiments proved that a large amount of contaminants is brought to the sea during floods. Furthermore, high proportion of contaminants discharged in the bay are exported offshore after a few days. Sampling grid design is crucial for effective comparison of pollution among different coastal settings - different coastal setups may require different monitoring approaches. Modelling facilitated the monitoring program design as it can assess a priori the behaviour and fate of pollutants under certain environmental conditions and hydrodynamics.

4. Conclusions/Discussion

The combination of field data with modelling capabilities is a valuable tool to help in designing monitoring programs and defining sampling grids in order to optimize resources and monitoring efforts for a better coverage and protection of the coastal areas. The study of spatial distribution of contaminants in surface water, by combining field data with modelling capabilities, provides knowledge on concentration of substances in relation to the distance from the coastline and input sources that can be applied to different environmental scenarios (e.g. characteristics of the coastal city, coastal setups, environmental conditions, hydrodynamics, etc.). This can be of special interest when selecting substances for monitoring programs, anticipating the domain where a substance could be of relevant concern considering distance to the coastline.

5. Acknowledgements

We would like to thank PERSEUS colleagues from IFREMER for the logistic support.

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Sedimentary aliphatic hydrocarbons, polycyclic aromatic hydrocarbons and trace metals in the open Aegean and NW Levantine Seas: Towards the assessment of MSFD D8

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Abstract
In this study, sedimentary aliphatic hydrocarbons, polycyclic aromatic hydrocarbons and trace metals in the deep/open Aegean and NW Levantine Seas are investigated. Our main goal is to assess their major sources and to report present-day concentrations and relevant information for the assessment of MSFD D8. Our findings highlight the role of deep Aegean and NW Levantine basins as repositories of anthropogenic chemical species and the multiple factors that overall control their distribution and fate.
Keywords: Deep basins, organic pollutants, inorganic pollutants, Descriptor 8.

1. Introduction

The Eastern Mediterranean Sea (EMS) is a marine setting under intense anthropogenic pressure. However, there is a lack of data regarding the occurrence of chemical pollutants in deep/open EMS settings. The Unresolved Complex Mixture (UCM) of aliphatic hydrocarbons pinpoints to chronic oil pollution while polycyclic aromatic hydrocarbons (PAHs) are a widespread class of organic contaminants. Trace metals in the marine environment play a dual role, either as essential micro-nutrients or as toxic agents, posing a risk for the degradation of the environment.

2. Materials and methods

Undisturbed surface sediments (top 1-cm) were collected across the open Aegean and NW Levantine Seas within the last two decades. All samples were analyzed by GC-MS for aliphatic hydrocarbons, and fourteen PAH compounds (parent and alkyl substituted) included in lists of priority chemical pollutants. Heavy metals were determined using the XRF method.

3. Results and discussion

Within the Aegean Sea higher UCM, $TPAH_{14}$ and heavy metals concentrations were recorded in the northern part (Fig. 1), revealing the importance of the Dardanelles straits and riverine inputs as sources of pollutants. In the south Aegean Sea lower concentrations of UCM and $TPAH_{14}$ probably relate to the absence of fluvial inputs and the oligotrophic character of the area, which results in lower accumulation of sedimentary organic matter and associated pollutants. Nonetheless, surface sediments at the southern Crete deep basins were found relatively enriched in Ni, Cu and Zn. The determined organic and inorganic chemical species occur at levels comparable to those reported for surface sediments in unpolluted coastal and/or open-sea areas.
The molecular profile of the determined organic compounds indicate an admixture of pyrolytic/ combustion sources, oil-derived pollution resulting in chronic oil pollution of surface sediments, and

biogenic inputs associated to higher plant waxes. Organic carbon exerts an important control on their transport and accumulation in the study area while variability of water masses also impact their regional characteristics (Parinos et al., 2013). The different heavy metal levels between the north and south Aegean Sea are attributed to the different sedimentological properties of the upper 30-50 cm, mainly due to their different supply mechanisms. In the north Aegean Sea the water and sediment load of major rivers seem to control their deposition patterns while carbonate sedimentation prevails in the south Aegean Sea (Karageorgis et al., 2005).

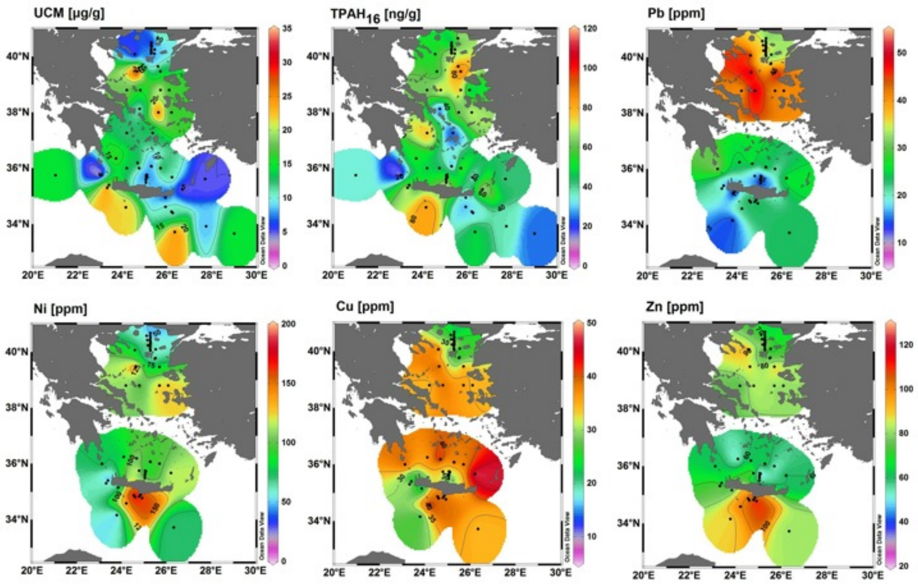

Fig. 1. Distribution of the sedimentary UCM, $TPAH_{14}$, Pb, Ni, Cu and Zn concentrations in the study area.

4. Acknowledgements

This work has been supported by PERSEUS (EU/FP7) & KRIPIS (MIS 451724; NSRF) projects.

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Spatio-temporal patterns of organic pollutants and heavy metals in Adriatic sediments

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Abstract.

Concentrations and fluxes of contaminants were measured in surface sediments and sediment cores in order to characterize source and sink of pollutants in the Adriatic Sea. The Po River resulted as the main source of pollutants. Concentrations decreased southward, although values in excess with respect to the background levels were measured also in the south Adriatic Pit and the Otranto Strait. An overall temporal decreasing trend was observed in most of the cores for all analysed contaminants, probably as a result of the application of discharge regulation. Offshore Bari, a recently contaminated area was detected.

Keywords: pressure levels of contaminants, temporal trends, deep sea sediments, Adriatic Sea

1. Introduction

The ADREX experiment focused to investigate the role of the Adriatic-Ionian system in transmitting the human-made pressures to the eastern Mediterranean. Our contribution was to provide data to better characterize origin, transfer pathways and fate of pollutants (Descriptor 8_Contaminants) from the Po River prodelta to the South Adriatic Pit by means of surface sediments and selected undisturbed sediment cores. This made possible to better define natural background concentrations and present levels of pollution for organic pollutants (e.g., PCB and DDT) and trace metals (e.g., Pb and Zn). In the Adriatic Sea, the dispersion of riverborne materials, and associated pollutants, is driven by the general cyclonic water circulation and oceanographic conditions. Consequently, fine sediments accumulate in a belt that parallels the Italian coast. River prodeltas are the areas of first deposition of riverine particles. The combined effects of waves, currents and biomixing are able to resuspend sediment particles from temporary deposits and disperse them along or across the continental shelf as far as their final repository. The sediment mass balance of the western Adriatic Sea has established that only ~10% of total riverine sediment supply may escape the accumulation on the continental shelf and reach the south Adriatic or be exported out the Otranto Strait. The cascading of NAdDW through the Bari canyon enhances particle transfer toward the deep basin. However, it is still completely unknown at what extent land-derived pollutants are transferred and accumulated in the south Adriatic sea.

2. Materials and methods

The sampling stations were chosen along transversal-to-the-coast transects and within the south Adriatic Pit taking into account the pattern of ^{210}Pb-based sediment accumulation rates. Sediment samples were collected in Nov. 2013 and Feb. 2014 with R/V G. Dallaporta. Furthermore, during the cruise ADREX-2014sed with R/V OGS-Explora in Oct. 2014, 8 sediment cores and 55 surficial sediments were collected between Trieste and Otranto. Sediment cores were sectioned in 1-cm thick slices down to the bottom, placed into pre-cleaned glass jars and stored at -20°C until analysis. For PCB determinations, samples were air-dried and Sohxlet extracted for 16 hours. Extracts were cleaned-up with acidic silica column chromatography. PCB levels were measured by GC with ECD equipped with an MDN-5S column. Concentrations of most of heavy metals were measured by GF-AAS (Zn by FAAS), according to the EPA methods 7010 and 7000B, after microwave-assisted digestion with an acid mixture (HCl, HNO_3, and HF, 3:1:1 v/v).

3. Results and Discussion

Low levels of PCBs (n.d.-8.0 μg kg^{-1}), if compared to highly urbanized coastal areas in the world, were measured in surface sediments. Concentrations declined from the Po River prodelta southward, suggesting the Po River as the major contributor of PCBs to sediments of the Adriatic sea. Not negligible values were recorded also in the south Adriatic Pit and the Strait of Otranto, implying that the anthropogenic pressure affects also the deepest ecosystems. The distribution pattern show some coastal increases suggesting that PCBs may also come from local sources (e.g., Ancona and Bari harbors). In the uppermost part of sediment cores, PCBs show a decreasing temporal trend, most likely reflecting the ban on PCB production and use in Italy due to European regulations starting since the '80s. An exception was recorded offshore Bari where a secondary peak suggests an additional local source of contamination from ~ 2000 AD. The general decreasing trend, however, is punctuated by large oscillations, which seem more related to sediment reworking processes rather than to the temporal input variability. Concentrations of Pb and Zn, showed similar trends with maximum values (³ 2-3 background levels) close to Po and Adige rivers, and deep in the sediment cores, and decreasing concentrations going southward and toward present time. In contrast, Cu concentrations remained close to background values. Again, the top of the core collected offshore Bari showed a sudden increase of heavy metals, further supporting the occurrence of a dumping site in the area.Metal concentrations in the south Adriatic were slightly higher than in the central Adriatic suggesting an additional particle source from the eastern side of the basin and supporting the need to apply the MSFD at basin scale.

4. Acknowledgments

This work has been partially funded by the EU FP7 PERSEUS Project (Grant no: 287600).

Floating litter in the Mediterranean and Black Seas: occurrence and distribution

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Abstract

Results from a large-scale visual survey of anthropogenic floating debris (>2 cm) carried out between 2013 and 2015 in the Mediterranean and NW Black Sea are reported. In both basins, similar densities and composition of floating debris were found and a mean abundance of 36.9±75.2 litter items/km² was found throughout the study area. Plastic consistently represented around 80-90% of all sighted items and the proportion of litter types remained generally constant in all surveyed regions. Despite a considerable spatial heterogeneity and some seasonal and inter-annual variations in litter concentration, no clear difference between the Mediterranean and the Black Sea emerged from our survey.

Keywords: Marine litter, plastic pollution, floating debris, Mediterranean Sea, Black Sea

1. Introduction

Litter accumulation is now recognized as one of the fastest growing threats to marine ecosystems worldwide. Its ubiquitous presence has been widely reported and by now, there is virtually no immune place left on earth. As such, marine litter was included among the 11 descriptors set by European MSFD (2008/56/EC), and all countries are now required to monitor its occurrence and abundance in the marine environment. Within this framework, we present results from a large-scale survey of floating debris carried out in the Mediterranean and Black Sea, providing new baseline information, which are urgently needed for initial assessment and proper management of the problem.

2. Survey methodology

The visual surveys were carried out during five cruises organized between 2013 and 2015 in the Mediterranean and in the Black Sea (Fig.1). Densities of floating debris were estimated using the line transect methodology (see: Suaria & Aliani, 2014 and Suaria et al., 2015 for more details). Observations were all made by the same observer, which during daytime navigation surveyed the sea surface from one side of the ship and recorded size, type, position and perpendicular distance of all sighted macro-debris items (>2 cm). The survey effort was split into 30-min transects (mean length: 8.8±2.0 km) and the exact distance covered during each transect was calculated from GPS start and stop positions. Litter densities (expressed as items/km²) were then computed over an area defined by the transect length and the Effective Strip Width (ESW), which was calculated for each cruise through distance sampling analysis (Buckland et al., 2005).

3. Results and Discussions

Two hundred and twenty four transect counts were performed for a total of 107.4 hours of observations (1937.9 km surveyed). A total of 1908 litter items were sighted, 83.7% of which were entire or fragmented plastic items, followed by styrofoam (12.6%) and others floating objects (3.7%) such as rubber, glass, metal, and cardboard. An overall mean abundance of 36.9±75.2 items/km² was observed throughout the study area, with maximum concentrations peaking to 878.6 items/km² in the Southern Adriatic Sea. Any clear difference emerged between the Mediterranean and the Black Sea and comparable densities were found in the two basins (37.3±79.8 vs 34.5±40.8 items/km² respectively). In 2013 an average of 30.9±40.7 items/km^2 were found in the Black Sea and similar densities were observed in the Adriatic Sea (31.5±30.9 items/km^2). Perhaps, because of seasonal increase in precipitation rate and river runoff, when repeating the measurements in 2015, much higher densities were found in both basins (Adriatic: 138.9±189.1 items/km^2, Black Sea: 61.3±34.8 items/km^2). Litter composition instead, remained almost constant in all periods and sub-basins examined, with plastic items consistently accounting for 80-90% of all sighted items.

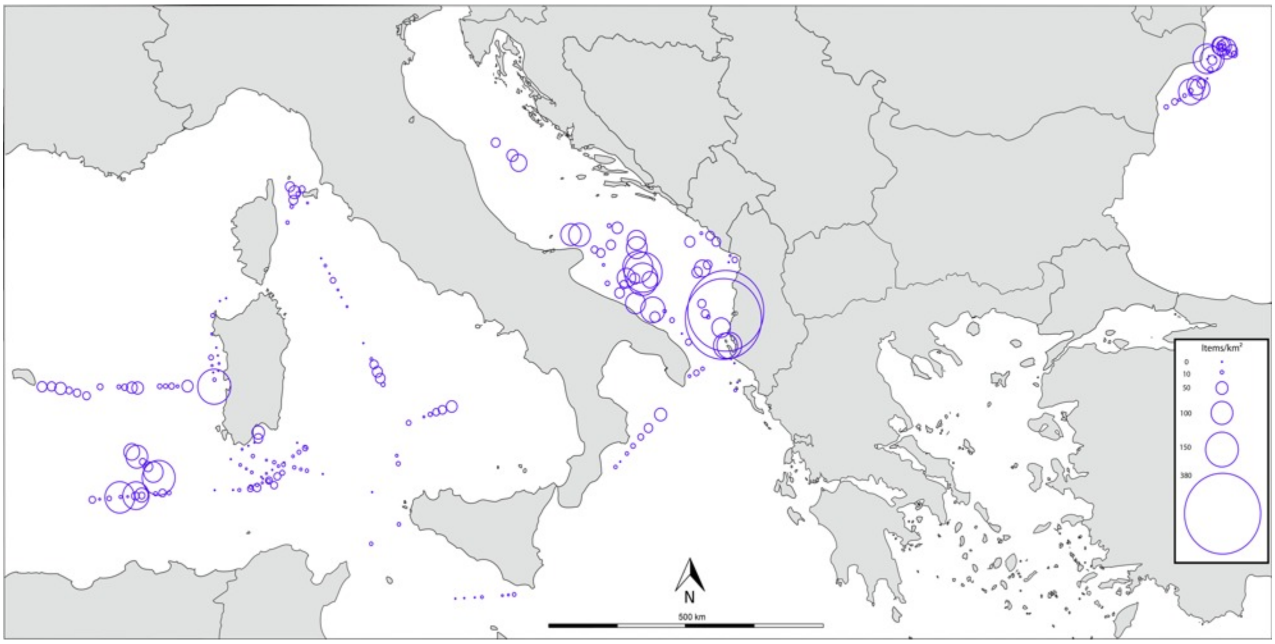

Fig. 1 *Map of the study area showing the observed litter densities (expressed as items/km^2). All cruises are plotted together (n=224 transects) and an outlier from the south Adriatic Sea (878.6 items/km^2) was removed for better clarity.*

4. Conclusions

Despite a conspicuous spatial heterogeneity in litter distribution, which is probably the ultimate result of complex interactions between ocean currents, prevailing winds, river outflows and human activities, our findings document the ubiquitous presence of anthropogenic debris in the two main European enclosed seas, providing further evidence that marine litter is a major socio-environmental issue which requires urgent attention by policy makers, managers and society.

4. Acknowledgements

We are thankful to MC Melinte-Dobrinescu (GeoEcoMar), M Borghini (ISMAR), and all captains and crew of research vessels 'Urania', 'Minerva Uno' and 'Mare Nigrum' for support during the cruises. Funding was provided by the EU-FP7 CoCoNET and RITMARE project funded by M.I.U.R.

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

The Outline of Marine Litter Collected During Demersal Fishing Surveys Organised in the Period 2011 – 2014 along the Romanian Black Sea Coast

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Abstract
This work describes the effort to monitor and record marine litter as a human derived contaminant, in the Romanian coast in the Black Sea. Most recordings come from haul measurements and additional expedition surveys, having documented several items all from plastic wastes.

Keywords: Black Sea, seabed, marine litter, plastic

1. Introduction

Marine life worldwide is contaminated with man-made litter. Plastic items consistently represent the major categories of marine waste by material type on a global basis. Plastic is extremely harmful: it damages fisheries and tourism, affects a wide range of marine life, has the capacity to transport potentially harmful chemicals and invasive species and can represent a threat to human health.

Although neither national nor regional programs are in place to monitor seabed litter in Romania, the National Pelagic and Demersal Fish Species Status Evaluation Program, which uses bottom sampling trawling, allowed the National Institute for Marine Research and Development to collect and assess types and quantities of marine litter on the seabed started on a voluntary basis and with the support of two European Projects Perseus and CleanSea.

The abundance and distribution of marine litter present on the bottom of the sea vary. Geographical distribution of waste is strongly influenced by hydrodynamic, geomorfological and human factors. In terms of items, plastic is by far the most abundant material, followed by processed wood and fishing nets.

2. Materials and methods

Fishing activities carried out from the Romanian Black Sea coast in order to assess the status of demersal fish stocks, have facilited also the collection of waste on the seabed. Thus, in the beginning of 2011 have been organized voluntary monitoring of waste during the National Program for Fish Data Collection , which targeted fishing activities with bottom trawl for obtaining the information necessary to assess demersal fish stocks .

In the year 2013, with the winning of a partnership within the framework of the project "Towards a Clean, Litter-Free European Marine Environment through Scientific Evidence, Innovative Tools and Good Governance, the opportunity arose to address a new research directions that favored to obtain data and information on marine waste situation in the Romanian Black Sea coast, establishing biological impact, socially and economically, the establishment of new monitoring technologies and techniques, collection and drawing up proposals for measures to support the policies for reducing their impact.

Monitoring of waste found along the shoreline (Vama Veche-Sulina) was done on a quarterly basis through direct observations, while the monitoring of waste on seabed was carried out through surveys, hauls made with bottom trawl in depths ranging between 20-80 m, on same traectory Vama Veche-Sulina. Sea expeditions have been conducted with the research vessel "Starfish 1" and the use of bottom trawl gear 22/27-34 m designed and realized by NIMRD Constanta. Hauls duration was 60 min, trawl speed was maintained at a constant value of 2.5 Nd and horizontal opening of the tool was 13 m, in which case the surface covered during research hauls was 60.190 m2 (0,06019 sq km).

3. Results

In the year 2011 was made only one expedition, in which 40 research hauls with demersal trawl were made, but waste has been identified only in 16 of them. As a percentage, relative to both the total quantity of waste (683,43 kg) and the total number of these (346 PC) collected from the areas covered during the 16 research hauls [c. 0,963 km2 (16 research hauls the waste have been identified x 0,06019 km2 the area covered in one haul)] (fig. 1), the situation of waste in kilograms, respectively, in the number of pieces per section is presented in figure 2.

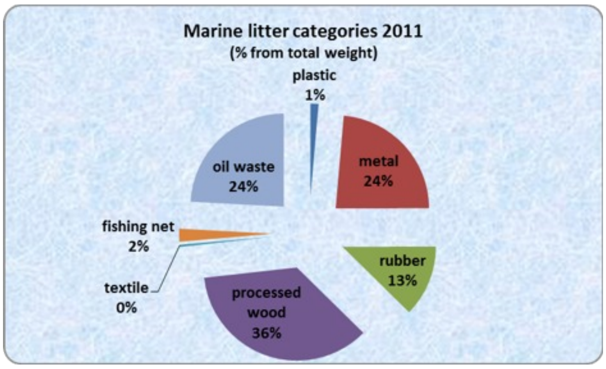

Fig.1

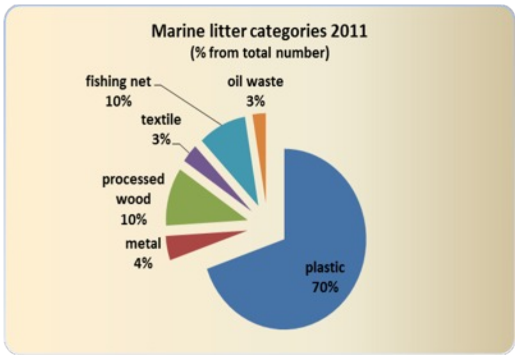

Fig.2

4. Conclusions/Discussion

The largest amounts of metal, plastic and toxic waste (used petroleum products in solid state or semi-liquid) and readily degradable materials (plastics) were located in the areas around the ports of Constanta, Cape Midia and Mangalia where is recorded a heavy naval traffic. Nearly in the majority of hauls were identified plastic waste (bags, bottles, bags, buckets, cans, linoleum, etc.). Plastic waste originating from throws performed aboard vessels/small boats coming out of the ports, namely those which run on commercial routes.

5. Acknowledgements

This research has been partially supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

Marine Litter Pilot Studies in Cilician Basin

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Abstract

In order to reduce or avoid both economic and ecological damage caused by marine litter and to comply with the aim of the European Marine Strategy Framework Directive (MSFD) of reaching a good environmental status of the European Seas by 2020, it is crucial to obtain information on the current state and source of pollution by coastal litter. In order to reveal the existing marine litter pollution and to provide baseline information on the problem several pilot studies were carried in compliance with the guidelines of MSFD GES Technical Subgroup on Marine Litter in the Cilician Basin.
Keywords: MSFD, Microplastics, Beach Litter, Plastic Ingestion

1. Introduction

The Cilician Basin is a densely populated and multi-use region where agricultural, touristic, fishing and industrial activities co-dominate. As in all other regions under anthropogenic pressures, marine litter pose a major problem for this one as well. Due to the lack of previous studies, a large knowledge gap exists on the status of the marine litter problem of the Cilician Basin.
The aim of this work is to provide up to date scientific description of the state of litter pollution and use it as a source of information for stakeholders working for the establishment of successful litter management plans in the region.

2. Materials and methods

EU sets a target as "Properties and quantities of marine litter do not cause harm to the coastal and marine environment" to achieve GES in EU marine waters related with marine litter problem. Within the last two years, we carry out several studies to provide sufficient baseline and monitoring information for the relevant indicator of "Descriptor 10" (Marine Litter) of the MSFD. All the studies carried out according to the proposed methodologies of MSFD GES Technical Subgroup on Marine Litter (JRC Scientific and Policy Reports 2013).

3. Results

Aiming to provide input for indicator 10.1.1 (Beach Litter), two studies were realized in the area. The first one is carried out to reveal the level of litter pollution, the major activities contributing to the pollution and the land-based origin of litter items in the Cilician Basin beaches in April 2014. In total 17,024 items were collected from the 13 selected beaches. The average litter density was 0.92 ± 0.36 items/m^2 and the average weight was 7.43 ± 2.68 g/m^2. According to the Clean-Coast-Index (CCI) (Alkalay et al. 2007) three of the sampled beaches were clean or very clean, two were moderate and eight were found to be dirty or extremely dirty. While the second study targets the evaluation of existence of macro litter on a model beach in Cilician Basin between 2013 and 2014 on a weekly basis. It was clearly observed that the amount of litter vary in parallel meteorological events and litter composition does changes depending on the seasonal use of the coastal areas.

Aiming to provide input for indicator 10.2.1 (Litter in Biota), we evaluate the existence of microplastic particles in the digestive system of fish species from the Cilician Basin in July 2015. Within the study, the stomach contents of 1428 individuals of 27 different fish species are to be analyzed.
Aiming to provide input for indicator 10.1.3 (Microlitter), two studies were realized. Within the first study, in monthly basis, existence and spatial change of microplastic particles on an unused model beach (METU-IMS) in Cilician Basin between September 2013 and September 2014 were evaluated. In the second study, with the monitoring purpose, in a broader area the existence of microplastic particles was annually evaluated on sea water and seafloor in the Mediterranean coast of Turkey (2014 - 2015). Laboratory assessments of the samples obtained from both studies are continuing.

4. Conclusions/Discussion

Data provided in all of pilot studies carried out are meant to provide a baseline for management plans concerning beach litter in the region.

5. Acknowledgements

This project was financially supported by The Scientific and Technological Research Council of Turkey (TUBITAK: 112Y394) through the MERMAID project "Marine Environmental Targets linked to Regional Management Schemes based on Indicators developed for the Mediterranean" (ERANET 12SEAS-12-C1) and DEKOSİM project (BAP - 08-11-DPT2012K120880

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Acoustic presence of sperm whales *(Physeter macrocephalus)* and delphinids in the Ionian and Aegean Seas, Greece.

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Abstract

The lack of information on the seasonal abundance and distribution of odontocetes in Greek waters hinders the establishment of effective measures for the management and conservation of endangered species. To collect baseline data on their occurrence patterns, two passive-acoustic recorders were deployed (a) in the Ionian Sea at Pylos Station (36.8N, 21.6E) and (b) in the northern Aegean Sea at Athos Station (40.0 N, 24.7E) in 2008 and operated for 19 months and 11 months, respectively. Preliminary results reveal the year-round presence of delphinid species at both locations. Sperm whales were almost exclusively detected in the Ionian Sea. Noise levels were generally higher in the Ionian Sea and associated with commercial and recreational shipping.

Keywords: Acoustic monitoring, cetaceans, Greek Seas, underwater noise

1. Introduction

Current data on the abundance and distribution of odontocetes in the Greek Seas were in the past primarily derived from visual surveys during the summer period, and focused on the Ionian Sea (Frantzis *et al.,* 2003). In contrast, we used a passive-acoustic recording system called the Passive Acoustic Listener (PAL) to study the seasonal occurrence of sperm whales and various delphinids in the Greek Seas. We furthermore analyzed the ambient sound levels at the deployment locations to assess current levels and trends of anthropogenic noise. This study represents the first year-round passive-acoustic monitoring effort in the Eastern Mediterranean.

2. Materials and Methods

The acoustic instrument used, the PAL, is a low-duty cycle (1.5%) passive acoustic recording system featuring a sampling rate of 100 kHz. The bandwidth of the recordings covers the frequency range of most vocalizations produced by odontocetes in the study area, except those produced by the harbor porpoise. Its limited memory capacity (~2 GB) allows 2,200 sound bites (raw acoustic data) of 4.5 s duration (a total of 165 min) to be stored during one-year deployment (Miksis-Olds *et al*., 2010).

Two PALs were used as part of the POSEIDON II project (http://poseidon.hcmr.gr/). The first was deployed for about 19 months (December 2008 - July 2010) at Station Pylos (36.8˚ N, 21.6˚ E) in the

Ionian Sea at a depth of 500 m (water depth 1,680 m). The second was deployed for about 8 months (November 2008 - July 2009) at Station Athos (40.0˚ N, 24.7˚ E) at 200 m depth (water depth 400 m).
An experienced analyst (ND) visually and aurally inspected the acoustic recordings using a custom Matlab-based analysis tool to identify bioacoustic signals of interest. Acoustic features of recorded echolocation clicks (inter click interval, frequency bandwidth, peak frequency, signal's length, presence/absence of whistles, etc.) were used to identify the vocalizing species. Daily presence/absence of these species was determined and seasonal occurrence patterns derived.
In addition, the instrument stored information on noise levels ever 5 min throughout the deployment. This information was used to produce plots of Spectral Probability Density distributions and determine the ambient sound levels at the two study sites.

3. Results

At Athos station, we have recorded many delphinid signals (clicks, burst pulse calls and whistles) throughout the deployment. The highest click detections occur during the months of December and January, and the highest whistles detections during April and March. The presence of delphinids is prominent at the location of N. Aegean Sea. On the other hand, the presence of sperm whales was verified only once, at the end of December 2008. The short deployment period does not allow the conduction of robust conclusions on seasonality of delphinids at this study area.

Our analysis reveals year round presence of sperm whales and dolphins at Pylos Station. The sperm whales are present during the whole deployment period but their occurrence does not present obvious seasonality. Comparing the two locations, the Ionian has higher cetacean activity than the N. Aegean. At Pylos, delphinids are present during an average of 65% of the deployment period, in contrast to a corresponding 45% at Athos. At Pylos we also detected higher ambient noise levels at low frequencies where shipping noise is the main contributor.

4. Concluding Remarks

The Passive Acoustic Listener (PAL) was originally designed to acoustically quantify wind speed and rainfall. This study demonstrates that the PAL can be used to cost effectively study cetaceans and anthropogenic noise for extended periods. The results provide valuable information on the seasonal presence of odontocetes in the Greek Seas as well as the levels and trends of ocean ambient noise.

5. Acknowledgements

The authors thank Sharon Nieukirk for her help reviewing the texts. This study was funded in part by the Hellenic Center for Marine Research (HCMR) and PERSEUS, the Office of Naval Research, and the Cooperative Institute for Marine Resources Studies (CIMRS).

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Drifter measurements during the Alborex experiment

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Abstract

Surface drifters deployed during the Alborex experiment in May 2014 allowed to investigate the surface dynamics in the eastern Alboran Sea. Inertial currents measured by the drifters were studied as a function of wind forcing and background circulation vorticity. The motions of drifters in closely-spaced clusters were decomposed linearly in terms of divergence/convergence, vorticity and stretching and shearing deformation rates.

Keywords: inertial currents, divergence

1. Introduction

A multi-platform and multi-disciplinary experiment (named Alborex) was carried out in May 2014 in the eastern Alboran Sea as part of the PERSEUS project. This process-oriented experiment aimed at studying submesoscale and mesoscale dynamics. Here we present the results provided by surface drifters released in a tight cluster across a front during Alborex. The study is focused on the near-inertial currents and the vorticity and divergence measured by the drifters in the vicinity of the front.2

2. Materials and methods

A total of 25 satellite-tracked drifters were deployed on 25 May 2014 in a tight cluster centered on a front. Following Poulain (1990) a least squares fit method was applied to the drifter velocities over 3-day boxcar time windows. For each time window, a CW motion was fit to the data with frequencies varying around the theoretical inertial frequency and the maximal explained variance was sought. The maximal amplitude, phase and frequency shift obtained by demodulation at the near-inertial optimized frequency were analyzed. The amplitudes of the drifter inertial currents were also compared to the NOAA/NCDC surface wind speed products. The effective inertial frequencies were related to the background circulation geostrophic vorticity as provided by AVISO satellite altimetry products to test the hypothesis of Kunze (1985) stating that the effective inertial frequency is shifted with respect to the theoretical value by half the local background geostrophic vorticity. The differential kinematic properties of fluid flow (divergence, vorticity, shearing and stretching deformation rates) are important elements in describing ocean currents dynamics. They were estimated following Molinari and Kirwan (1975) using all the drifters for the first few days after deployment.

3. Results

During the period 25 May - 8 June 2014, the drifters deployed more to the south were quickly captured by the Algerian Current; near 5°E they turned northward. Drifters deployed more to the north moved southeastward for ~100 km then were deflected northward. The frequency shift of the near-inertial motions was analysed for all the Alborex drifters. It is predominant positive differences during the period 25 May – 8 June 2014, in particular for the drifters captured by the Algerian Current along the north African coast. The relation between the vorticity of the background geostrophic circulation field and the effective inertial frequency was studied. The slope coefficient estimated from the linear regression of inertial currents smaller than 5 cm/s is about 0.16 (skill of ~16%). This value is substantially smaller than 1, the value of Kunze (1985), but there is a clear positive correlation of the inertial frequency shift with the background geostrophic vorticity. The differential kinematic properties of flow field in the vicinity of the front were computed considering the cluster of all the drifters for 2-3 days are deployment. After a few hours from deployment, the vorticity remains essential positive and the divergence varies in 0-2 10^{-5} s^{-1}. The relative variance explained by the linear decomposition varies quite a lot with time. In the zonal direction, it can even reach almost 100%.

4. Conclusions/Discussion

The surface drifters released in the eastern Alboran Sea allowed to study several aspects of the circulation in a strong front. Inertial currents are ubiquitous along the drifter trajectories, reaching amplitudes of > 15 cm/s. They are characterised by frequency shifts related to the vorticity of the background circulation. Linear decomposition of the drifter velocities indicates that the front is divergent at the surface, possibly corresponding to upwelling in its core, and has positive vorticity. All these results are important to understand mixing mechanisms related to the Marine Strategy Framework directive in the Mediterranean Sea.

5. Acknowledgements

The Alborex experiment was conducted in the framework of PERSEUS EU-funded project (Grant agreement #287600) with substantial support from SOCIB and OGS. The altimeter products were produced by Ssalto/Duacs and distributed by AVISO, with support from CNES. The wind products were downloaded from the NOAA website.

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The Mediterranean components of the Spanish Institute of Oceanography Observing System, IEOOS

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Abstract
The Instituto Español de Oceanografía (IEO) maintains a large and coherent ocean observing system around the Iberian Peninsula, the Canary and the Balearic Islands. The IEO Observing System (IEOOS) provides quality controlled data and information about Spanish surrounding waters and comprehends several subsystems. Within the IEOOS and along the Spanish Mediterranean coast, the RADMED monitoring program is conducting several of the evaluations required under the MFSD. The different aspects of the ecosystem that are regularly sampled are the physical environment and the chemical and biological variables of the water column, together with the planktonic communities, biomass and structure. Determinations of some anthropogenic stressors on the marine environment, such as contaminants and microplastics, are under development.
Keywords: Observing Systems, Operational Oceanography, Spanish waters

1. Introduction

The Instituto Español de Oceanografía, IEO, Observing System, IEOOS (Lavín, 2014), incorporates different observing systems including deep moorings and surface-meteorological moorings, tide gauge networks, a satellite reception station, the Argo-Spain network, regional oceanographic observatories, continuous R/V sampling systems, periodic R/V surveys and modelling facilities. The IEO has promoted the RADIALES program (Valdés et al., 2002), as a structural activity, for the acquisition and analysis of regular temporary series of oceanographic data around the Spanish coasts. The multidisciplinary observations (physical, chemical, biological) are done in a time scale that sample oceanographic events in all the seasons of the year and successive years, what allows to discriminate between the different variability sources.
Included in the IEOOS in the Mediterranean Sea, the RADMED project "series tempoRAles de Datos oceanográficos del MEDiterráneo" (time series of Mediterranean oceanographic data), was established by the IEO in 2007 (López-Jurado et al., 2015). It was designed to integrate previous monitoring programs developed by different IEO Centres along the Spanish Mediterranean coast some of them running since the 90's.

2. Methods: RADMED general sampling strategy

Water column T, S, DO, fluorescence and turbidity are sampled in every oceanographic station. Chlorophyll-a and inorganic nutrients along the water column are sampled using a carousel water sampler at standard depths. pH, total Alkalinity and partial pressure of CO2 in air and surface water have been included in the RADMED sampling strategy since 2010. Phytoplankton and zooplankton are sampled by Niskin bottles and bongo nets to determine their biomass and taxonomic composition. The RADMED monitoring program samples regularly every 4 months (to filter the seasonal variability) a fixed distribution of stations, arranged on transects normal to the bathymetry from the coast to the bottom of the slope (to characterize the self-slope gradient and the coast-open sea gradient), alongside the Spanish Mediterranean coast, from Barcelona to the Alboran Sea and around the Balearic Islands (to characterize the meridional gradient). All the stations are sampled from the surface the bottom. The temporal coverage is enough to characterize the physic-chemical environment but is in the limit for a detailed description of the biological (pelagic) habitats. The spatial coverage should be increased by including one or two long transects to close the boxes to allow for deep water masses transport analysis.

All RADMED CTD and biogeochemical data are integrated into the IEO Data Centre (CEDO, Centro Español de Datos Oceanográficos) following standard procedures and after that are incorporated into the SeaDataNet infrastructure (http://www.seadatanet.org/). Data is fully accessible through it. In parallel, all the CTD data, nutrients and chlorophyll-a are included into the IBAMar database (Aparicio-González et al., 2015). IBAMar database at standard levels is freely available for exploration and download from http://www.ba.ieo.es/ibamar/

3 Results: Relevance of the RADIALES and RADMED monitoring programs for the MSFD requirements

The RADMED and RADIALES historical series have been incorporated to the report on Initial Assessment of the Current Environmental Status and GES in the Spanish waters whose conclusions are available at the Spanish Ministry of Agriculture, Food and Environment (MAGRAMA) website http://www.magrama.gob.es. Mean values, seasonal oscillation and long term trends together with spatial distribution of the different oceanographic environmental variables are included on that reports. Both programs are included in the Proposal of Monitoring Programs as multipurpose platforms for the implementation of the MSFD in Spain. It is expected that they will continue providing information for D1, D4, D5 and D7. There are other descriptors required by the MSFD that could be easily implemented within the RADMED cruises like the study of microplastics in the open sea by Neuston nets or performing dredges at critical points to characterize also the sediment contaminants.

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An hydraulic winch to support deep CTD casts using small boats

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Abstract

Long-term ocean monitoring strategy requires affordability, efficiency and longevity of research infrastructure. To support these efforts, an autonomous portable winch for small boats able to cast down to 1000 m depth at constant speed (1 m/s) a load of up to 25 kg, was constructed and tested successfully. The numerous advantages compared to an electric winch of similar specifications are discussed.
Keywords: cost-effective monitoring, time-series, small R/V

1. Introduction

One of the objectives of PERSEUS (WP3) is to upgrade-expand the existing observational systems and develop a long-term monitoring strategy. Such planning needs advances in research infrastructure considering science questions, affordability, efficiency and longevity. HCMR is maintaining since 2010 a time series in the open Cretan Sea (POSEIDON E1-M3A station). To be cost and time effective, cruises are mainly performed with a small fast boat. The winch capacity of this boat limited the depth of casts to 200 m, and the load to 15 kg (in air). This winch (electric) gave the required wire speed (1±0.3 m/s), using the maximum power capacity (280 Watt) for a 12V DC motor found in the market. The aim of the present study was to construct an autonomous portable winch that can be installed on a small boat, able to cast to 1000 m depth at constant speed (1±0.1 m/s), with instruments load up to 25 kg (in air).

2. Materials and methods

Autodesk Inventor software was used to design the hydraulic winch and to calculate stresses and deformations. The winch is composed by three units: A) oil tank, hydraulic pump, clutch, internal combustion engine; B) drum, wire, hydraulic motor, clutch, bidirectional analogue control valve, automatic hydraulic brake, manual emergency brake; C) bracket, wire length-speed meter (Table 1, Fig. 1). Wire winding is controlled by moving manually a pulley. A detachable crank handle is intended for emergency use in the case of power failure. The winch was installed on a RIB of 5.25 m (OSPREY Viper, V haul, dead weight capacity 1150 kg) and tested in the Cretan Sea.

3. Results

The system was deployed successfully in the Cretan Sea allowing CTD casts down to 1000 m at a constant speed of 1±0.1 m/sec, using a small boat. It can carry instruments up to 25 kg (e.g. CTD + 3 x 5lt NISKIN bottles).

Table 1. *Winch specifications*

Table 1. Winch specifications

Material	AISI 304 stainless steel
Drum:	O.D./I.D. 320/200 mm, width 180 mm
Payload & Drum Wire	a) 25 kg in air (wire: Ø 2mm, L=1200 m, 30 kg - break load 240 kg) b) 60 kg in air (wire: Ø 3mm, L=500 m, 18 kg - break load 515 kg)
Wire speed	1±0.1 m/s
Speed-length counter	Electronic, wireless
Brakes:	-Automatic Hydraulic -Manual emergency
Power:	Internal combustion engine
Oil tank	20 lt
Weight	160 kg (wire included)

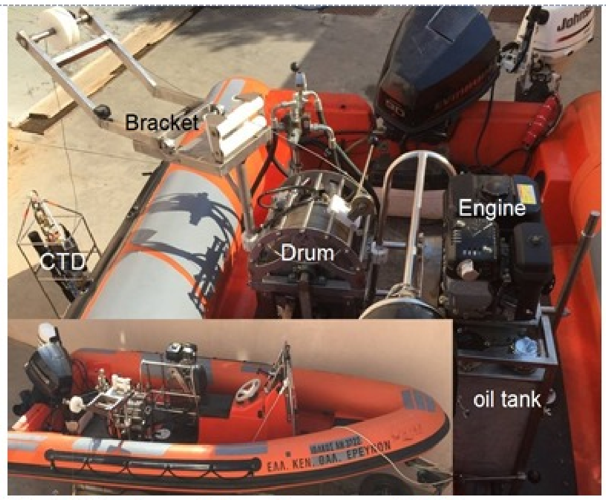

Fig.1 Winch positioned on a small RIB.

4. Conclusions/Discussion

An hydraulic winch was chosen to provide reliability, efficiency and reduced maintenance for a system exposed to harsh open sea conditions. A comparison was made with an electric winch (230 VAC/1500 W) of similar specifications (wire length-speed, max payload, for small boats, constant speed) available in the market. Although fuel consumption (for the electric power generator) and volume occupied in the boat were similar, the hydraulic system had several advantages. Besides avoiding the use of 220V on a small boat exposed to sea spray, the hydraulic system is more reliable and lighter (160 vs 200 kg – wire and power generator included). Finally the cost of the hydraulic prototype (6 K€ for consumables) was lower than the cost of the electric winch (15 K€ excluding power generator). The only disadvantages encountered are the required installation time and that automated fine control of wire speed is better and easier with an electric system. Possible upgrades are incorporation of slip ring, automatic wire winding and counter controlled by Arduino. It can be adapted to higher payloads by changing the wire and if necessary the drum.

5. Acknowledgements

The construction was partly funded by the EU IP Project FP7 – PERSEUS (Grant Agreement No 287600). We would like to thank Technomatic Control S.A. for providing the hydraulic circuit preliminary diagram, as well as G. Piperakis and M. Ntoumas for their helpful comments.

Recent Decline of the Black Sea Oxygen Inventory

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Abstract

After a reduction of the open Black Sea oxygen content during the eutrophication period (1970s and 1980s), the increase of oxygen inventory in 1985–1995 supported arguments in favor of the stability of the oxic layer, and the convenient perception of a Black Sea recovering from eutrophication. Instead, we show on the basis of in-situ profile analysis that the Black Sea oxygen inventory has decreased by 36% from 1955 to 2013, while oxygen penetration depth decreased from 140m to 90m. The transient "recovery" mainly resulted from high dense water formation rates, which is foreseen to be limited by atmospheric warming.

Keywords: Deoxygenation, Eutrophication, Ventilation, Cold Intermediate Layer.

1. Introduction

In the Black Sea, a permanent pycnocline separates a low salinity surface layer from an unventilated high salinity deep layer that hosts the world's largest reservoir of toxic hydrogen sulphide. Around the pycnocline, a permanent suboxic layer separates the oxic ($[O_2]<20$ µM) and sulphidic ($[H_2S]>20$ µM) interfaces. The vertical stability of these interfaces was warmly debated during the past decades (e.g., Murray et al, 1991, Buesseler et al. 1994, Konovalov and Murray, 2001), as a significant shoaling (1960-1985) and then stabilization (1985-1995) was observed. While the balancing impacts of eutrophication and Cold Intermediate Waters formation (as the main ventilation mechanism) have been recognized (Konovalov and Murray, 2001), the time scales of their interactions has never been solved and long-term investigations covering pre- and post-eutrophication phase as well as different air temperature cycles were missing.

2. Materials and methods

We computed three oxygenation diagnostics from a composite historical set of 4467 ship-based vertical profiles (1955-2013): oxygen penetration depth (where $[O2]=20\mu M$), oxygen penetration density level and oxygen vertical inventory. We then used the DIVA detrending algorithm (Capet et al., 2014) to identify and dissociate the spatial variability of these diagnostics from their temporal variability. ARGO profilers (2010-2012, Stanev et al. 2013) provided independent estimates for the recent values of the oxygenation diagnostics and for the range of their spatial variability.

3. Results

The spatial analyses (not shown here) indicate that the use of pycnal coordinates does not free from significant spatial variations of oxygen penetration depth. The concentration of recent ship-based profiles in areas of deeper oxygen penetration might thus have led to an underestimation of the ongoing shoaling of the Black Sea oxic interface, which reveals when spatial variability is considered (Fig. 1). Comparison of oxygen inventories and CIL cold content indicates that the transient stabilization (1985-1995) was induced by a decade of high ventilation rates, masking ongoing high oxygen consumption rates after the reduction of nutrient load.

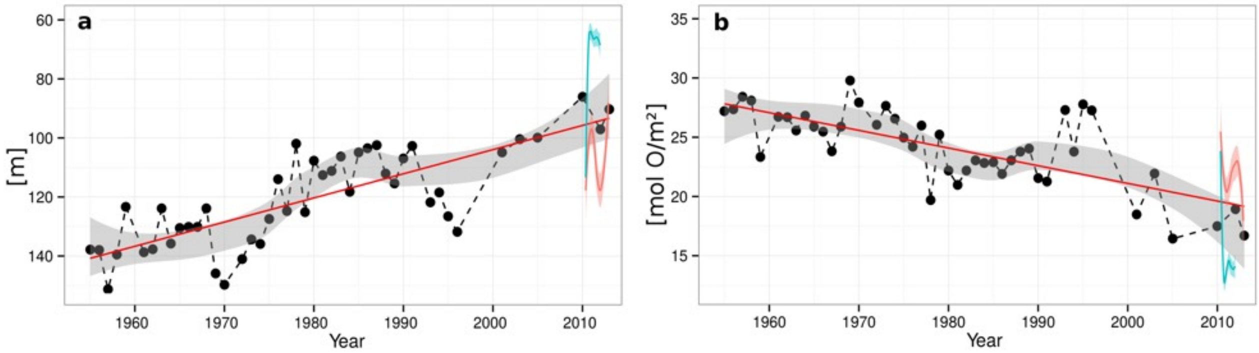

***Fig.1** Modern trends of **(a)** oxygen penetration depth and **(b)** oxygen inventory. Dots: Annual trend derived from the DIVA analysis. Red : linear trends over 1955-2013 are **(a)** -8.2 m and **(b)** -1.4 mol O /m² per decades. Colored contours indicated the diagnostics derived from a coastal (red) and a central ARGO floats.*

4. Discussion

Forecasted global warming will reduce the ventilation of the Black Sea intermediate layers, while uncertainties remain regarding the capacity of re-flourishing economies of the lower Danube watershed to recover their productivity in a less polluting form (Kroiss et al., 2006). Under these conditions, there is no reason to expect that the oxycline shoaling observed over the past 60 years will stabilize. Close monitoring is required to assess the risk of affecting the Black Sea living stocks and that of chemocline excursion events during exceptional storms.

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Modelling pelagic ecosystem health in the Western Mediterranean. A PERSEUS contribution.

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Abstract

The Vigor (V), Ecosystem Organization (EO) and Resilience (R) of the pelagic domain of the Alboran Sea were analyzed through a multiple modelling approach. Two horizontal domains and two vertically integrated measurements (10 and 100m) were analyzed through 1989-1998 and 1999-2008. A scenario-based analysis was adopted for 2010-2020. Trends in V decreased significantly in 1999-2008 only in the North. 100m-integrated production yielded different seasonal patterns in each spatial domain. Results suggest that the EO strongly depends on the Atlantic Jet dynamics. We provide potential scenarios of change based on existing knowledge.

Keywords: Vigor, Ecosystem Organization, Resilience, Alboran Sea

1. Introduction

Current knowledge relates the Atlantic Jet (AJ) dynamics in the Alboran Sea (AS) with the production of both low trophic levels (LTL, Oguz et al., 2013) and high trophic levels (HTL), the latter in connection to the Kinetic Energy (KE, Ruiz et al., 2013), largely affected by meteorological conditions (Navarro et al., 2011). Strong perturbations of the usual AJ patterns should affect the "health" (usual state) of the ecosystem. We here assume that i) by modelling the KE in connection to a coupled biogeochemical model of the AS, we can track observed ecosystem properties such as Vigor (V, production), ecosystem organization (EO, based on selected indices) and Resilience (R, rate at which a system recovers from a perturbation) through time and 2) that by using empirical relationships we can link modelled KE with HTL, and put it in the context of LTL changes. We aim at providing insights into the past variations of Vigor, Ecosystem Organisation and Resilience during two decades, and comment on the potential trends up to 2020.

2. Materials and methods

We modelled Vigor and Ecosystem Organisation for two past time-slices (1989-1998 and 1999-2008), whereas Resilience was analyzed based on a model-detected (and observationally checked) large perturbation in 2001. We modelled the monthly biomass of two sizes of phytoplankton (SPHY, LPHY) and two of zooplankton (SZ, LZ) from a coupled and tested 3D ROMS-$N_2P_2Z_2D_2$ model (Peliz et al. 2013; Macías et al. 2014). We obtained averages at two horizontal (whole AS and the Northern AS) and two vertical levels (10 and 100m). The trends in Vigor were calculated through General Linear Models on monthly anomalies of total phytoplankton and total zooplankton, separately for each time-slice. The Ecosystem Organisation anomalies were inspected through two sets of *indices: index 1 was based on looking at the ratios of the anomalies (a) of small trophic fractions (aSZ/aSPHY) vs the "typical" large fractions of the system (aLZ/aLPHY). Index 2 looked at the relative anomaly variation of large vs small primary and secondary producers (aLPHY/SPHY, and aLZ/SZ). The analysis of Resilience was based on analyzing the recovery dynamics of the LTL (mechanistic model) and HTL (observational) in response to the major disturbance in KE (see results). Scenarios* *of change for 2010-2020 are recreated based on potential states of the model-derived KE as the driving force of the system, as the required ensemble models incorporating NAO etc are unavailable (IPCC 2014).*

3. Results

The modelled Vigor was higher in the Northern AS in both time slices. Strong positive anomalies were detected in 1996 and 2001, coinciding with field observations (Ruiz et al., 2013). Significant differences in Vigor existed between time-slices in the North AS when depth was integrated over 100 m: the slope of the anomalies decreased in 1999-2008, concurrently with lower average Chla values in the second (climatological) half of the year. The KE was positively correlated to production at lag=0, with maximum values observed for the North AS at the surface. At LTLs, the Ecosystem Organisation showed that large phytoplankton excelled in the North AS. No trends in Ecosystem Organisation were apparent but Ecosystem Organisation singularities were detected, induced by small plankton dynamics. The HTL was linked to LTL changes in Ecosystem Organisation through statistical modelling of the anchovy recruitment in the North AS. Values for Resilience could not be properly inferred, but a proxy showed that at least for the LTL and anchovy fisheries the system was re-established in <12 months. By using a scenario-based analysis, we suggest that it is highly improbable that a rapid change in the ecosystem health is observed in the AS unless a sustained modification of the AJ is substantiated.

4. Conclusions/Discussion

We showed that by applying a high resolution coupled biogeochemical model to the time-slices of PERSEUS, we were able to detect not only the main dynamics but also the main anomalies of the LTLs. The KE reasonably predicts these dynamics, and can be linked either mechanistically or statistically to changes in Vigor, Ecosystem Organisation and Resilience not only of the LTL but of higher trophic levels. Although some trends were detected, under our mechanistic hypothesis future changes in the Vigor in the coming 5 years will depend on our capacity to project the dynamics of the Atlantic Jet, which will not be feasible unless an ensemble of adequate pressure indices (e.g. NAO) are available for the future. Therefore, although no dramatic changes are foreseen at the short-term, changes due to increased climate-change are possible at longer time-scales.

5. Acknowledgements

This research has been supported by the project: "Policy-oriented marine Environmental Research in the Southern EUropean Seas" (PERSEUS, EC 7th FP).

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Remote sensing and regional bio-optical models for the Black sea ecosystem productivity assessment in line with MSFD

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Abstract

The application of recent advance of modelling allows to monitor the natural variability of indicators at different temporal and spatial scales in operative mode, which provides necessary information to establish reference values, to define operative target and formulate management measures and track the feedback of ecosystem to measures.

Keywords: Black Sea regional algorithm, chlorophyll, colored detrital matter, GES.

1. Introduction

Following European marine policy (MSFD, 2008) Good Environmental Status (GES) is described by several indicators corresponding to eleven descriptors. Ocean color sensors information gives new opportunities in oceanography due to its spatial and temporal scales of observation. Monitoring of ecosystem productivity based on remote sensing data could provide information required for GES assessment of several indicators. Application of the remote sensing approach for GES assessment requires a set of regional algorithms based on the bio-optical peculiarities and the phytoplankton photo-physiological characteristics of the Black Sea, which can transform correctly optical data of satellite sensors into ecological characteristics: chlorophyll a concentration (Chl-a), biomass of phytoplankton, size structure of phytoplankton (PSD/PFT), water transparency, suspended and dissolved organic matter light absorption coefficient, total and new primary production (PP). These regional algorithms are based on the output of the Chl-a algorithm. Consequently, the accuracy of the Chl-a algorithm determines the correctness of the productivity indicators assessment by the corresponding algorithms.

2. Materials and methods

The standard global SeaWiFS algorithm for Chl-a retrieval (OC4) is not correct for the Black Sea - in summer overestimates and in spring - underestimates phytoplankton bloom (Suslin et al., 2014). For the Case 2 conditions (colored dissolved organic matter (CDOM) concentration is relative high and absorption does not correlated with phytoplankton absorption) occurring often in the Black Sea, an algorithm has been developed (Suslin et al., 2008) based on three bands, two ratios semi-empirical approach for retrieving of Chl-a and absorption by colored detrital matter (aCDM, where CDM = NAP + CDOM) in the Black Sea. After SeaWiFS terminated operation, it was required to adapt this algorithm to MODIS and MERIS spectral bands. The new adapted algorithm (to MERIS and MODIS bands) allowed to get merged product (Chl-a and aCDM(490)) with most complete spatial coverage (Suslin et al., 2014), which is crucial especially for cold season, when atmosphere is cloudy very often. The regional algorithm is based on an optical algorithm for seawater that is simplified and parameterized with a regional tuning procedure for distinct water types in the Black Sea (Suslin et al., 2008). The algorithm takes into account the regional peculiarities in parameterization of phytoplankton light absorption (Churilova et al., 2008). The regional Chl-a algorithm was validated by comparison with Chl-a and aCDM(490) measured in-situ.

3. Results

The application of the Chl-a algorithm allowed to construct long-term series of Chl-a and aCDM(490) for different Black Sea regions. Based on anomalies of Chl-a, aCDM(490) and SST, differences in frequency, intensity and time of blooming were identified for regions with different mechanism of nutrient supply. The blooms in deep-waters are correlated with nutrient enrichment of upper mixed layer associated to intensive convective mixing during cold period. Inter-annual variability of bloom intensity is related to winter meteorological conditions. In the near Danube shelf waters, phytoplankton “blooms” are associated with riverine nutrient enrichment, which control the inter-annual variability of “bloom” intensity and frequency. Finaly, aCDM(490) could be used as a marker of river runoff intensity and variability between years (Fig.1).

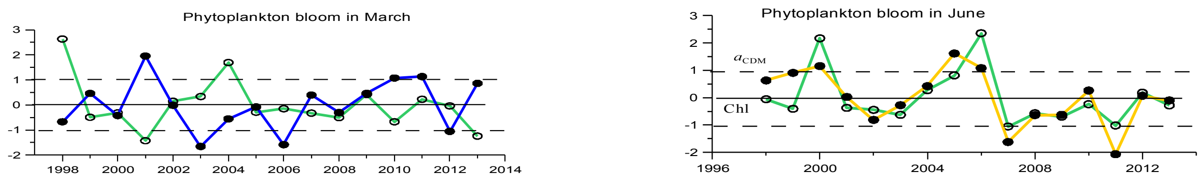

Fig. 1 *Interannual variability of phytoplankton bloom intensity (green), SST in preceding winter (blue) and aCDM(490) (yellow): presented as anomalies.*

4. Conclusions/Discussion

The application of recent advance of modelling allows to monitor the variability of indicators at different temporal and spatial scales in operative mode (Korotaev et al., 2014), which provides necessary information to establish reference values, to define operative target and formulate management measures and track the feedback of ecosystem to measures.

5.Acknowledgements

The research has been done with financial support of FP 7 projects DEVOTES, PERSEUS, MyOcean-2 and GSFC NASA, RFFI regional projects No 14-45-01594, No 14-45-01595, No 14-45-01516.

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Hindcast and future scenario of the Black Sea dynamics and ecosystem changes

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Abstract
Long-term evolution of the Black Sea dynamics is reconstructed by means of numerical simulation using the Black Sea circulation model. The model was driven by atmospheric forcing functions simulated by CMCC. To assess the quality of the Black Sea circulation dynamics, derived from simulation, the modelling results were compared with results of the Black Sea physical reanalysis, performed by assimilating the temperature and salinity profiles from hydrographic surveys. The hydrophysical fields from modeling results were then used for simulating long-term changes of the low trophic level ecosystem.
Keywords: Black Sea dynamics, marine ecosystem.

1. Introduction

An important problem of modern oceanography is the assessment of the climate change impact on marine ecosystems. The Black Sea ecosystem underwent considerable changes in the sixties – eighties. These changes, severely altered in particular, biomass, taxonomic composition and the community structure of plankton groups. In addition to nutrient load factors influencing these variations, climate changes attributed as well. Climate changes can be dominant factors in launching some risk processes, particularly in such semi enclosed seas as the Black Sea, exerting strong impact on ecosystem health. The issue is to understand how the Black Sea ecosystem will react to these changes, and, as the first step, to evaluate the environmental status of the basin, under current and scenario conditions. The present work is devoted to the simulation of the long-term variability of the Black Sea dynamics (hindcast and future scenario) as a basis for modeling the low trophic level (LTL) marine ecosystem.

2. Materials and methods

The model of the Black Sea circulation is a z-coordinate model based on the traditional primitive equations (Korotaev et al., 2011) with horizontally uniform grid (4.8 km resolution) and 40 vertical levels compressed to the sea surface. As boundary conditions on the sea surface we used atmospheric forcing functions prepared in the Euro-Mediterranean Center on Climate Change (CMCC) using regional climate model COSMO-CLM.
The LTL ecosystem model (Dorofeev et al., 2013) extends from the sea surface to 200m depth with 26 z-levels. It includes 15 state variables. Nitrogen is considered as the only limiting nutrient for phytoplankton growth.

3. Results

Using the Black Sea circulation model, briefly described above, we obtained hydrophysical fields for four decades (1980 – 2020). To evaluate its quality we compared them with results from the Black Sea physical reanalysis (Knysh et al., 2012) which was performed by assimilating the temperature and salinity profiles into the circulation model. The comparison showed a quite good capacity of the circulation model in simulating the main thermohaline features of the Black Sea. The seasonal cycles of temperature and salinity were well captured. The main deviations in temperature were observed in the narrow subsurface layer of seasonal thermocline. Model salinity in the surface layer was overestimated in comparison with the reanalysis. That can be caused by inadequate description of the river runoff in the model. As an example fig.1 demonstrates the difference in temperature between results of modeling and reanalysis.

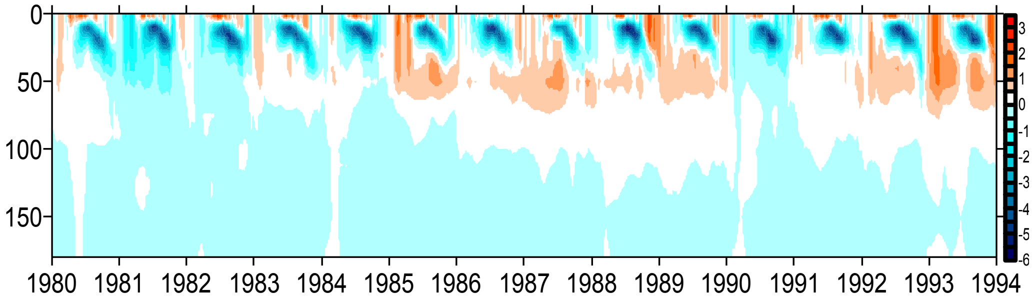

Fig.1 *Distribution of basin-averaged differences between modeling temperature and reanalysis.*

The most significant deviation can be observed at the depth of about 20m, where model values of temperature are smaller than reanalysis one during spring-summer season. In the lower layer (40 – 100m) the modeling temperature is mainly higher, so the CIL in our results contains warmer water than in the reanalysis case.
The hydrophysical fields were then used for study a long-term evolution of the Black Sea LTL ecosystem. The results demonstrated changes in the marine ecosystem. In particular, biomasses of the main plankton groups grew in eighties – early nineties and then its values descended to the levels of early seventies. These changes in plankton biomass were also accompanied by modifications in the vertical geochemical structure.

4. Conclusions/Discussion

The simulation of the Black Sea circulation dynamics was fulfilled for the past four decades. The modeling results were compared with reanalysis data (1980 – 1993). This comparison showed that the model describes the Black Sea thermohaline structure and its seasonal and interannual variability sufficiently. Simulation of the Black Sea ecosystem evolution, performed on the basis of physical modeling results, demonstrated changes in marine ecosystem, which, in general, correspond to field measurements conducted in 60s – 90s.

5. Acknowledgements

This study is a contribution to EU 7th Framework project PERSEUS (GA 287600) EC FP7/2011-2015.

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Dynamics of the marine ecosystem on the continental shelves of the Northwestern Mediterranean – (WP4 PERSEUS)

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Abstract

The productivity and organization of the planktonic ecosystem have been studied through numerical modelling of 3 regions of the NorthWestern Mediterranean margin. Contrasted features have been noted between the northern regions (e.g. Gulf of Lion) and the southern region (Catalan margin, south of Ebro). In the northern regions, phytoplankton productivity is inhibited in December but is high in March and zooplankton remains productive from spring to autumn. In the southern region, zooplankton is less developed in summer but remains twice more concentrated in early winter.

1. Introduction

Despite the many physical and biogeochemical observations that were made for several decades on the Gulf of Lion shallow areas, very little information on the organization of the ecosystem and its relation with forcing by the meteorological conditions and rivers is available. As a first attempt to better understand the organization and the productivity of the marine ecosystem on the nortwestern Mediterranean shelves, a modelling approach was carried out.

2. Materials and methods

A coupled hydrodynamic and biogeochemical model has been used to simulate a 13-year period from 2000 to 2012 in the western Mediterranean. The 3D hydrodynamic model SYMPHONIE (Marsaleix et al., 2008) was coupled to the biogeochemical ECO3M-S using 3 groups of phytoplankton and of zooplankton (Auger et al., 2011, 2014). Three regions were considered and compared: the Gulf of Lion, the Catalan margin (north from Ebro and from Ebro to Valencia). The objective was to highlight similarities and differences between these regions and to relate them to environmental conditions.

3. Results

The meteorological fluxes for the three regions present a similar qualitative behaviour with maximum heat losses in winter; however this feature is increased in the Gulf of Lion. Rivers discharge are maximum in the Gulf of Lion but their influence is certainly evident in the Northern Catalan region. First the simulated chlorophyll was compared to the satellite values from MODIS (Fig. 1) for our 3 selected regions. The agreement is rather good with generally a realistic representation of the timing (maximum values in winter) and of the annual cycle.

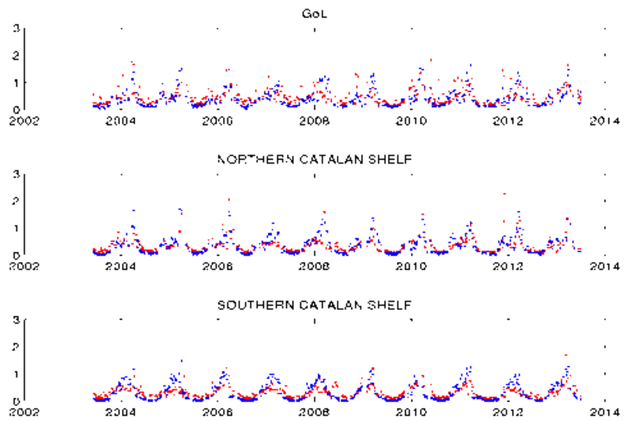

Fig.1 *Comparison of chlorophyll simulated (blue) and MODIS (red) averaged over three shelves*

The northern Catalan region has a relatively similar behavior to the Gulf of Lion while the southern Catalan region is distinguished by an earlier bloom (~1 month). The northern regions present indeed an inhibition of phytoplankton production in December, while in the south the production regularly increases from October to February / March. On the other hand, production is larger in northern regions during the peak of late winter and in summer especially in the Gulf of Lion. In winter, zooplankton has a large disadvantage to the north but is well developed on the southern Catalan. By contrast, in summer, zooplankton is more developed in the Gulf of Lions in summer, probably also linked to a stronger development of phytoplankton. There is an interannual variability of these characteristics with, during cold winters, minimum zooplankton in winter counterbalanced by increased phyto and zoo plankton peaks in late winter and spring respectively. Concerning the phytoplankton structure, microphytoplankton seems to respond quickly to peaks of the rivers discharge and is also positively correlated with winter heat losses.

4. Conclusion

The margins of the NorthWestern Mediterranean present contrasting functioning of the planktonic ecosystem. Numerical modelling indicate that on the northern margins (Gulf of Lion and north Catalan), cold winter conditions strongly inhibit planktonic development in December and January while the ecosystem is more productive from March to November (this is especially true in summer in the Gulf of Lion presenting relatively high levels of zooplankton). On the contrary, the southern Catalan margin presents a peak of productivity of zooplankton in winter and low concentrations in summer. Such differences should impact the structure of higher trophic levels.

5. Acknowledgments

PERSEUS (WP4) and the French Mermex /Mistrals project.

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Upgrades and expansion of the existing observing systems in the Mediterranean and the Black Sea

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Abstract

The protection and preservation of the marine ecosystems of the South European Seas (SES) has been a focal issue of PERSEUS FP7 project. The identification of the human-driven and natural pressures on the marine environment implies the sustainability and upgrade of the SES monitoring capacities. Hereby, an overview of the upgrade and expansion activities of the existing oceanographic observing networks is presented. Specifically oriented towards addressing MFSD, the SES upgraded monitoring network is providing relevant information such as new biochemical and ecosystem parameters, hydrological variability and estimation of noise levels that is presented through selected examples.

Keywords: Fixed-point stations, oceanographic surveys, biochemical parameters, underwater noise, PERSEUS FP7

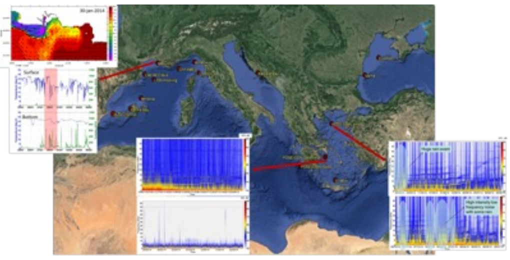
1. Introduction-Activities carried out

During the last two decades several initiatives aimed towards an integrated and sustainable operational monitoring network for the Mediterranean and Black Sea. The SES mooring network has been leading this effort consisting of coastal and open sea Eulerian observatories that monitor a variety of atmospheric and water physical and biochemical parameters. Such initiatives could not have been undertaken without the synergy of the Research Vessels fleet that contributed with repeated cruises to measure additional parameters and provide datasets valuable for the assessment of the acquired time-series from moorings. In this work, an overview of PERSEUS work on the overview of the upgrade and expansion activities of the existing oceanographic observing networks is presented.

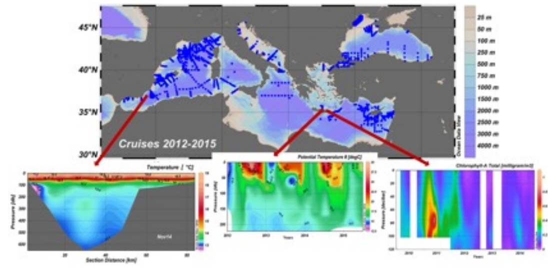
2. Results

The work on “Multi-parametric moorings, new sensors, upgrade and expand” (PERSEUS sub-task 3.2.1) that focused on the upgrades implemented for open sea moored observatories and selected coastal stations in the Mediterranean and Black Seas is being detailed in the relevant deliverable (Deliverable D3.2 Kassis et al., 2014)

During the last 3-years period, 16 moored stations have been upgraded with new sensors (figure 1) while 72 cruises were carried out (figure 2) under sub-task 3.2.3 “R/V repeated monitoring; increase spatio-temporal resolution and support upgrade/ expand existing surveys” (PERSEUS deliverable D3.7 Schroeder et al., 2015). Both served the scope of filling in the gaps and address the “Review of ocean observing systems in the SES and recommendations on upgrades to serve PERSEUS needs” (PERSEUS deliverable D3.1 Poulain et al., 3013) outcomes. Selected examples from the acquired data are also shown**.**



(fig.1)



(fig.2)

Fig.1 *The fixed point stations that have been upgraded under PERSEUS 3.2 task. Examples presented: a particles resuspension event at the bottom took place in January 2014 after strong South and East wind that induce strong waves (top left). The upgraded Passive Aquatic Listener that was deployed on Saronicos station produces datasets of much higher resolution allowing a better the estimation of the ambient noise (bottom). Long timeseries that were acquired from an old generation PAL that have been deployed in Athos station, allowed estimations of strong rain and wind events.*

Fig.2 *All the research cruises conducted within PERSEUS project in the SES between 2012 and 2015 to fill the gaps identified in task 3.1. Substantial improvement is to be highlighted for the Algerian Basin, the north-western Mediterranean, the north-eastern Mediterranean and the Black Sea. The southern Ionian Sea is still under-sampled (not sampled at all during Perseus), but this has to be mainly ascribed to political issues and ongoing conflicts in the southern shore countries. Diagrams of temperature and chlorophyll-a at the E1-M3A station in the South Aegean Sea, as much as the temperature field in the Mallorca-Ibiza channel are presented (bottom).*

3. Conclusions/Discussion

Several indicators for the Good Environmental Status (GES) will require significant contribution from the in-situ observing components in order to be addressed. The estimation of quantitative descriptors such as eutrophication, alternations of hydrography and noise, are some examples of how in-situ observations can contribute to MSFD. The upgrade process should be continuous and well planned, at a national and European level, in order to move towards the fulfillment of the scientific and society needs.

4. Acknowledgements

This work is supported by PERSEUS FP7 project

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Interannual variability of the Black sea chlorophyll related with wind and circulation patterns identified by the Self-Organization Map analysis

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Abstract

The main objective of this research is to study the interannual variability of the Black Sea chlorophyll concentrations which related with the forcing of physical factors (SST, wind, sea circulation) and/or influence of climate variability. The Self-Organization Map (SOM) analysis was applied to identify typical (recurrent) spatial patterns of chlorophyll concentrations and physical forcing data. The results of SOM analysis are compared with time variability of the climatic indices (NAO, EAWR).
Keywords: SOM, chlorophyll, QuikSCAT, interannual variability, Black Sea, NAO, EAWR

1. Introduction

The interannual variability of the chlorophyll concentrations has the maximum values on the North-western Black Sea shelf, which is impacted by riverine waters with rich nutrient concentrations. But in this research we focus mainly on the influence of the physical forcing (SST, wind, sea circulation) and long-term variability of large-scale structures which could be associated by climatic indices: North Atlantic Oscillation (NAO) and East Atlantic-West Russia (EAWR).

2. Materials and methods

The phytoplankton blooms in the deep part of the Black Sea are related with nutrient fluxes to the upper layer due to intensive convective mixing influenced by the wind forcing. Therefore, the monthly composite chlorophyll data of SeaWiFS, MODIS, MERIS with 4.6 km spatial resolution for the Western Black Sea part and surface wind of QuikSCAT (http://winds.jpl.nasa.gov/missions/quikscat/) for all sea area were analyzed for 1998-2012 years period.

The Self-Organization Map (SOM) analysis was applied to identify typical (recurrent) spatial patterns from chlorophyll concentrations and physical forcing data (A. Capet et. al., 2012).

The chlorophyll six SOM patterns have the frequency of occurrence (in % from total number of maps): 8%, 3%, 16%, 26%, 22% and 25%. SOM-1 is associated with bloom on the western shelf in June; SOM-4, SOM-6 are mainly corresponded to others are shown the transition between them. Interannual variability of best matching unit (BMU) time series of chlorophyll concentrations is shown on Fig.1a (black solid line). The QuikSCAT wind six SOM patterns have the frequency of occurrence: 17%, 14%, 16%, 21%, 20% and 10%, their basin averaged wind curl is positive for SOM-1 and SOM-5 and corresponds to cyclonic occurrence patterns, while the other SOM has negative wind curl and corresponds to anticyclonic wind. Three-months cumulative SOM of QuikSCAT wind (color bars) versus of chlorophyll BMU time series are presented on Fig.1a.

3. Results

The deep-water chlorophyll bloom occurs mainly during winter period (February-March) when cyclonic wind are more intensive. SOM № 5 and №6 demonstrate the recurrent spatial patterns of chlorophyll concentrations, the cyclonic typical wind patterns (SOM № 1 and №5) correspond them during this period (Fig.1a).

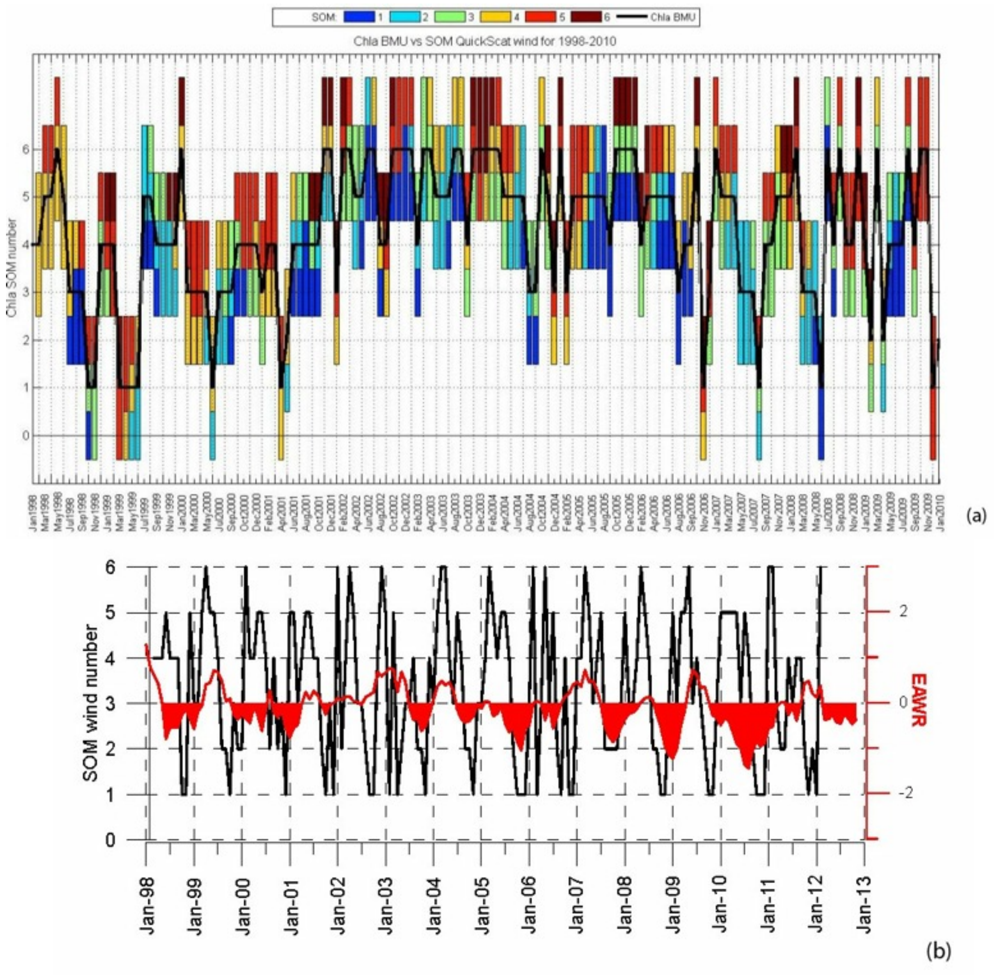

***Fig. 1** Interannual variability of best matching unit (BMU) of chlorophyll concentrations (black solid line) versus three-months cumulative SOM of QuikSCAT wind (color bars) for 1998-2010 (a); and best matching unit of QuikSCAT wind (black solid line) versus EAWR climate index (red fill line) for 1998-2012 (b).*

The influence of Large-scale climate variability on the time sequence of wind recurrent patterns is estimated by the comparison with climate indices (NAO, EAWR). The maximum mean wind curls SOM-1 (cyclonic) and SOM-4 (anticyclonic) correspond to the highest NAO index values in negative (1998; 2008; 2010-2011) and positive (1999-2000) phases, so western wind patterns occurrence are mainly associated with prominent NAO values. The significant EAWR values are positive in 1997/98, 1999, 2003, 2007 and correspond to SOM-5 and SOM-6 which are mainly described the southerly winds patterns (Fig.1,b). EAWR index is negative in 1998, 2000, 2005/2006, 2009, 2010 and mainly corresponds to the SOM-1 (northerly winds) during these events.

4. Conclusions/Discussion

The application of SOM analysis for the chlorophyll concentrations and physical forcing data permits to classify the recurrent bloom patterns related with the cyclonic winds which in return correlate with persistent climate indices. The synergy forcing of sea circulation features derived from the satellite altimetry and SST on the interannual variability of blooms will be presented on the poster also.

5. Acknowledgements

This study is the contribution to EU 7th Framework project PERSEUS (GA 287600) EC FP7/2011-2015.

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Scientific Conference
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Improving the monitoring and simulations of the Black Sea influence on the Aegean

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Abstract

Several steps have been taken to improve (a) the monitoring of the plume of the Dardanelles inflow into the Aegean, mainly through the use of a coastal High-Frequency radar installed on the east coast of Lemnos island, and (b) the numerical simulations of the North Aegean sea, mainly focusing on improving the parameterization of Black Sea Waters inflow and assessing the role of high-frequency, small-scale phenomena on the interannual evolution of the hydrographic properties of the basin. The HF radar is used both for validation of the model results, and for direct estimation of the BSW inflow volume fluxes.
Keywords: North Aegean Sea, HF radar, BSW, interannual variability.

1. Introduction

The buoyancy exchange between the Black Sea and the Mediterranean controls to a large degree the characteristics of the North Aegean Sea . Furthermore, the inflow of Black Sea waters fertilizes the North Aegean, thus maintaining a significant gradient of oligotrophy along the Aegean basin and supporting the largest part of the Greek, and a significant part of the Turkish coastal fishing fleets (Stergiou et al., 1977; Siokou-Frangou et al., 2002). Recent state-of-the art projections of the evolution of the Mediterranean circulation and hydrographic conditions in the 21st century have simply parameterized the exchange between the two Mediterranean and the Black Seas, thus not considering the Strait internal dynamics and the evolution of the Marmara Sea. In this work we attempt improvements in the North Aegean simulations by introducing tidal forcing, assessing the effects of different turbulence closure schemes, distributing more realistically the solar radiation within the surface layers and exploiting a HF radar-deduced as well as simulated Black Sea outflows into the North Aegean.

2. Materials and methods

The HF radar "Dardanos" (Kokkini et al., 2014) has been used for the continuous monitoring of the surface circulation in the area between Dardanelles (North Aegean exit) and the eastern part of Limnos island and the quantification of the outflow of the Black Sea into the Aegean. For the numerical simulations, the Regional Ocean Model System (ROMS, Haidvogel et al., 2000) was used. Boundary conditions for about 30 years were provided by Pinardi et al. (2015). Lateral forcing was provided by Maderich et al. (2015) and the atmospheric forcing by the EMCWF ERA interim data set.

3. Results

Our results show that the time varying Dardanelles outflow parameterization (provided by Maderich et al., 2015) significantly improved surface circulation in comparison to using a perpetual year outflow. The spatially varying distribution of solar radiation improves the surface fields and affects the deep water formations rates. The HF radar has been used both for model evaluation and for the assessment of the Black Sea volume outflow into the Aegean. Finally, the model simulations suggest that the deep basins exhibit both interannual and annual variability.

4. Conclusions

The availability of ARGO float and CTD profiles in the deep N. Aegean basins makes it possible to assess the performance of a range of turbulence closure schemes in laterally secluded basins, thus enabling the improvement of long-term simulations (both forecasts and hindcasts) without the use of relaxation. Furthermore, the adoption of new methodologies (hydraulic Strait models) and tools (HF radars) can significantly improve our modelling and observing capabilities.

5. Acknowledgements

The project "Policy-oriented marine Environmental Research for the Southern European Seas – PERSEUS", funded by the E.U.'s F.P. 7 programme (FP7-OCEAN-2011-3287600) funded this work. We are grateful to Professor Nadia Pinardi for her advice and support.

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Establishment of a long term offshore sampling transect in the Eastern

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Abstract
The Continuous Plankton Recorder (CPR) collects marine plankton in repeated coast to coast transects over long periods of time. This paper describes the first employment of the CPR in the Eastern Mediterranean Sea by team from The Cyprus Institute and its operation in the Levantine. First results indicate increased productivity near the southern rim of the Levantine and at an offshore location characterized by decreased surface temperatures. The continued survey will provide unique information on plankton abundances in the Levantine Sea.
Keywords: Continuous Plankton Recorder, Levantine, plankton, MedCPR, Cyprus

1. Introduction

Plankton, drifting aquatic plants and animals, can provide information on temporal and spatial patterns, food web interactions and regime shifts over the years (Siokou-Frangou *et al*., 2010). The integration of different plankton studies in the Mediterranean is hampered by a decreasing sampling gradient eastwards, southwards and as we move away from coastal areas and towards open waters. Today there is only one long term offshore zooplankton sampling station in the Mediterranean, while coordinated efforts to cover larger parts of the Mediterranean are sporadic (e.g. Dolan *et al*., 1999). To close the gap, the EU FP7 project PERSEUS initiated a long term plankton survey in the Mediterranean Sea with the collection of biological samples along coast to coast transects, by a Continuous Plankton Recorder (CPR). Here we describe the first CPR survey operated by a Mediterranean country (MedCPR) and the first sampling efforts in the Eastern Mediterranean through the description of the November CPR tow along the Larnaca/Vasiliko, Cyprus to Haifa, Israel transect (Fig. 1).

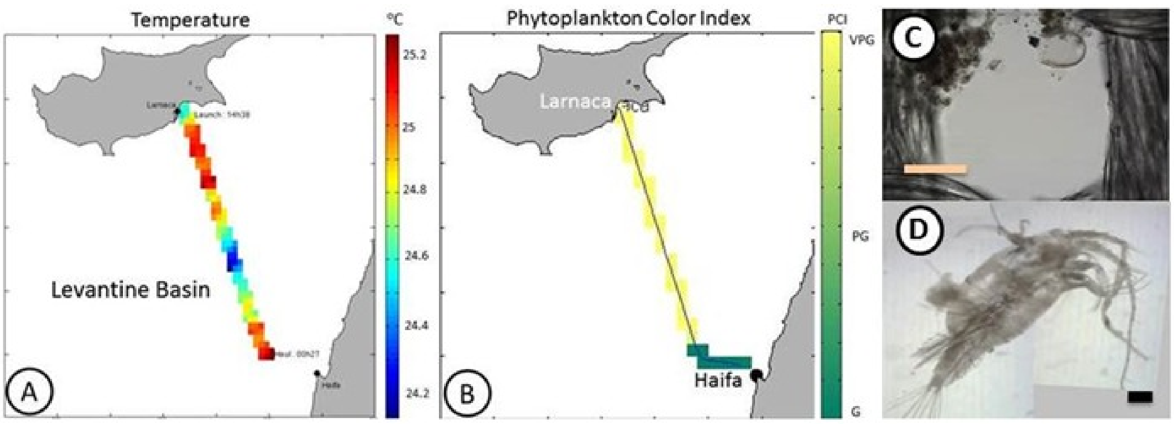

Fig.1: *Temperature (A) and Phytoplankton color index (B) for the November 2014 transect (G: Green; PG: Pale G; VPG: Very PG), interpolated along the sampled transect (black line (B)). Protists (C) and mesozooplankton (D) alternate dominance along the CPR transect. (Scale-bar: 0.2mm)*

2. Materials and methods

The CPR is a robust mechanical device, towed monthly by a ship of opportunity since fall 2014, at 6-10m depth, along a vertical transect between the south coast of Cyprus and Haifa. (Fig. 1). Apart from phyto- and zoo-plankton abundance and species composition, a method called Phytoplankton Colour Index (PCI) assesses biological productivity, while a miniature conductivity, salinity and depth sensor adjusted on the CPR collects physical data. Sample analysis takes place at the CyCPR Facility, on the premises of The Cyprus Institute, Cyprus.

3. Results and Discussion

The Levantine Sea is oligotrophic, with productivity peaks near coastal and water masses mixing areas (Siokou-Frangou *et al*., 2010). PCI and plankton abundance information from the tow that took place on November 5, 2014 shows higher productivity near the coast of Haifa (Fig. 1b). Protists, a characteristic of Mediterranean oligotrophic gradient (Dolan *et al*., 1999), are the most abundant group in samples near the Cypriot coast providing 64-45% of the total number of individuals, with decreasing southern abundance towards the more productive end of the transect; when dominance shifts towards mesozooplankton (Fig. 1c-d). Long term PCI data and its integration with satellite information, may provide Levantine-wide in-situ information required to uncouple primary productivity information from the presence of particulate matter (Groom *et al*., 2005) and its link to higher trophic groups.

CTD data show warmer coastal waters and a temperature drop offshore (Fig. 1a), which coincides with a peak in zooplankton abundance, at an identified convection area (e.g. Groom *et al*., 2005). This early observation provides insight into the possible uses of MedCPR datasets in locating productivity oases of the Levantine Sea and for connecting them to physical data.

The MedCPR, has marked the beginning of a baseline database for the Levantine to fill the gap in information about offshore populations. The expansion of the Suez Canal, temperature increases and intense hydrocarbon exploration are expected to impact the Levantine marine environment. The availability of a long term survey able to deliver physical and biological data, during and after these developments will provide vital information to scientists and stakeholders of the region for the management and monitoring of environmental change.

5. Acknowledgements

The authors would like to thank Columbia Shipmangment Ltd, Lefkaritis Marine Bros Ltd., and the master and crew of the PETROLINA OCEAN tanker for their voluntary participation in the survey. We would also like to acknowledge Cecelia Hannides, Marina Evriviadou and Audrey Delpech.

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A new generation end-to-end model producing forecast products to enhance marine GMES applications in the Black Sea

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Abstract

A new generation end-to-end (circulation, biogeochemical and a higher trophic level) model for the Black Sea was developed to provide an integrated analysis of ecosystem attributes that contributes to the criteria relevant to the MSFD descriptors. The biogeochemical model, including the carbonate module, comprises of thirty state variables. The model system was used to carry out hindcast analyses for 1980-2013 period and forecast analyses for the 2013-2020 time periods, assuming different scenarios in the anthropogenic pressure acting on the Black Sea. The results indicate that the Black Sea model system demonstrates a range of skill, with physical variables having the most skill followed by chemical variables. The HTL model has more skill for small pelagic fish (e.g. Anchovy) than larger pelagic and demersal fish. Future scenarios indicate a variety of challenges the Black Sea ecosystem may have to face.

Keywords: Black Sea, ecosystem models, HTL models

1. Introduction

The Black Sea, one of the major semi-enclosed seas of the world oceans, has experienced striking ecological changes under concurrent impacts of climate change, intense eutrophication, and population explosion of invasive species, unsustainable fishery, and their density-dependent feedback processes. Therefore, end-to-end Integrated Modelling System for the Black Sea has been developed to set-up the next generation modelling system to assess environmental health of the ecosystem. The goal is to benchmark the quality of the hindcast simulation, to inform end-users about the skill and hence usefulness of the simulations, and then to provide future simulations of the status of the Black Sea with predictive abilities.

2. Materials and methods

The Black Sea model system consists of three models, namely a physical model, a lower-trophic-level model (LTL) and a higher-trophic level model (HTL), coupled in an end-to-end fashion. The physical model used for the Black Sea is an implementation sbPOM and its domain includes the whole of the Black Sea. Hindcast analyses were done for the 1980-2013 period and forecast analyses for the 2013-2020 time periods assuming “business as usual” conditions in the anthropogenic pressure acting on the Black Sea were undertaken.

The LTL model contains thirty state variables that include four phytoplankton types, four zooplankton types, oxygen, hydrogen sulphide, inorganic nutrients and detritus in both nitrogen and phosphorus currencies as well as the carbonate system variables. The simulation was performed for the same time frame as the physical forcing generated by sbPOM, 1980-2020.The HTL model used in this project for the Black Sea is the Ecopath with Ecosim (EwE). The model includes 23 functional groups and is parameterised using spatial averages of the required LTL compartments and flows between them as detailed in Libralato and Solidoro (2009).

3. Results

The modeling system has been extensively validated using available data from the Black Sea. The results demonstrate that the Black Sea model system has a range of skill, depending on the variables chosen. Physical variables (e.g. T, S) generally have the most skill, followed by chemical variables (e.g. O_2, Nutrients) then plankton variables (e.g. chlorophyll) for the coupled hydrodynamic LTL models. The HTL model has more skill for small pelagic fish (e.g. anchovy, sprat, and horse mackerel) than larger pelagic and demersal fish. In addition to the five climatological scenarios of PERSEUS (BAU, BA, MFA, RBE, REB), we tested three additional scenarios of anthropogenic stressors on 2010-2020 BAU: i) +/- 30% fishing mortality of all fish; ii) +/-30% of fishing mortality of small pelagic fish, and iii) +/-30% fishing effort of trawlers.

4. Conclusions/Discussion

The modeling system is currently being used to investigate Vigor, Organization and Resilience of the Black Sea ecosystem and hence is an advanced tool to predict Good Environmental Status in the region. Specifically, the descriptors D4 of the MSFD (food webs), D1 (Biological Diversity) and D3 (commercial fish) of the EU directive on Good Environmental Status can be assessed with this modeling tool.

5. Acknowledgements

This research has been partially supported by the project: “Policy-oriented marine Environmental Research in the Southern EUropean Seas” (PERSEUS, EC 7th FP).

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Micro-, nano- and pico-phytoplankton distribution in the Mediterranean Sea from ocean colour data

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Abstract

Chlorophyll a is the most common used variable in ocean colour studies. It represents the base of several algorithms able to determine the contribution of each phytoplankton group to the total chlorophyll a content. In this work, we investigated the applicability of a chlorophyll-based algorithm on Mediterranean basin, born to identify three Phytoplankton Size Classes (PSCs), micro-, nano- and pico-phytoplankton from satellite data. We also discussed the algal community distribution at different spatial and temporal scales.
Keywords: Dimensional Classes; Remote sensing; Plankton; SeaWiFS

1. Introduction

Phytoplankton represents the base of trophic web and its role in the carbon cycle, as well as in other biogeochemical mechanisms, is crucial. The heterogeneity of in situ data does not allow a global knowledge of the phytoplankton distribution, thus the satellite approach represents a potential instrument used to define a synoptic mirror of the phytoplankton dynamics (Sathyendranath et al., 2014).

2. Materials and methods

We studied the phytoplankton variability at different spatial and temporal scales applying the Brewin et al. (2011) model (hereafter BR) on the regional satellite chlorophyll *a* product. Considering the optical characteristics of the Mediterranean Sea, we tested on a Mediterranean pigments dataset the *in situ* phytoplankton size classification (Sammartino et al., 2015, and references therein), using regional and global coefficients, and we compared the results with the BR satellite model curve. Our analysis demonstrated that a regionalization of the *in situ* PSC classification function reduces the error (MBE% from -4 to 21 %) to values comparable with those obtained by Brewin et al. (2010) at global scale (MBE% 11-13%), suggesting that the BR, even if set for the global ocean, can still be used in the Mediterranean Sea (Sammartino et al., 2015).

3. Results

The results confirmed that the distribution of the three PSCs at local scale is deeply variable, being influenced by particular physical and biogeochemical processes (Fig 1). The maps and temporal series showed that the pico-phytoplankton predominates in oligotrophic conditions, as those of the Levantine basin (Fig. 1), while the larger cells, as micro, prevail in high nutrient conditions. During the spring season, micro-phytoplankton cells are abundant in some offshore areas characterized by a strong dynamic of water masses and convection events, which allow the uplift of nutrients (Fig. 1).

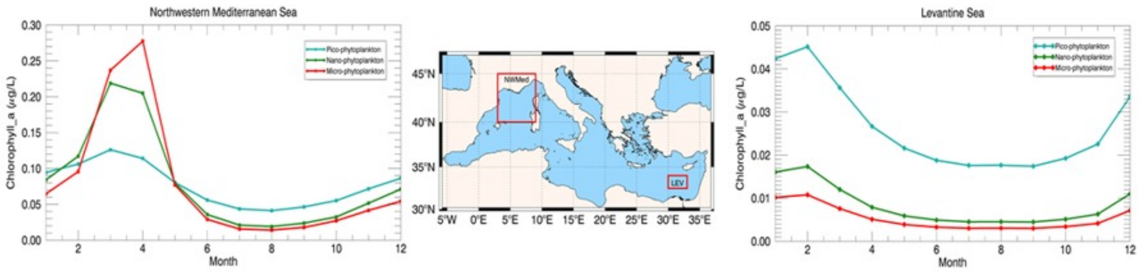

***Fig. 1** Monthly climatological series of Micro (red line), Nano (green line) and Pico (light blue line) Nor Northwestern Mediterranean Sea (left panel, NWMed in map) and Levantine Sea (right panel, LEV in map).*

4. Conclusions/Discussion

Sensors installed on space-borne platforms can detect the community composition. The results, obtained applying the Brewin et al. (2011) model on the Mediterranean chlorophyll *a* products, are in accordance with the *in situ* data and the events described in the literature. They confirm that rich nutrient waters favour large cells, as micro-phytoplankton, followed by nano fraction, while pico class appears more suitable to live in poor nutrient condition.

5. Acknowledgements

This work was financially supported by the EU project FP 7 PERSEUS (Policy-oriented marine Environmental Research in the Southern EUropean Seas) Grant Agreement No. 287600 and the Italian RITMARE Flagship Project. This work was also supported by MyOcean-2: Prototype Operational Continuity for GMES Ocean Monitoring and Forecasting Service (Grant Agreement 283367).

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Jellyfish monitoring in Cyprus with the help of public

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Abstract

Here we present the first results from a four year study (2012-2015) on the use of citizen science for recordingthe species and abundances of jellyfish which occur in the coastal waters of Cyprus. In the total duration of this study 60 reports and 11 species of jellyfish were reported from the waters of Cyprus, with Mnemiopsis leidyi and Cassiopea andromeda being the most abundant and most frequent reported species. The majority of jellyfish recorded observations were from the east coast of Cyprus in comparison with the west coast.

Keywords:Jellies, Citizen science, Eastern Mediterranean.

1. Introduction

Jellyfish are conspicuous, but relatively an under-studied component of the marine ecosystem. Their populations fluctuate widely with ocean climate and also experience sudden outbursts known as "blooms", followed by population crashes (Brotz 2012). The periodicity of occurrence of some jellyfish species has shorten in recent decades and the recurrence of blooms has increased at both local and regional scales, probably due to food web modifications and climate change (Acevedo et al., 2013). This study aims to i) record the species of jellyfish which occur in the coastal waters of Cyprus, ii) record the size of jellyfish blooms, and iii) investigate the changes occurring in jellyfish populations.

2. Materials and methods

This study focused on the "citizen science" approachto record jellyfish. Citizens along with agencies and organized groups associatedwith the sea (i.e. diving centers, fishermen, NGOs) were requested to contribute by recording species of jellies that are found inall coastal areas of Cyprus. Citizens were asked to provide sightings of jellyfish through adedicated webpage. The webpage, http://www.oceanography.ucy.ac.cy/medusa/home.html, contains the description of the main species that occur in the Mediterranean,and an online form which the public can use to submit their sightings. The public is also requested to give information on the region, date, no.of individuals, density of bloom, etc.Awareness and dissemination activities were implemented through newspapers articles, radio interviews and posters. This activity started in Cyprus in 2012 and continuous up to date.

3. Results

In the four-year-duration (2012-2015) of this study 60 reports and 11 species of jellyfish were reported from the waters of Cyprus: *Aurelia aurita*, *Carybdea marsupialis*, *Cassiopea andromeda*, *Cestum veneris*, *Chrysaora hysoscella*, *Cothyloriza tuberculata*, *Mnemiopsis leidyi*, *Olindias phosphorica*, *Pelagia noctiluca*, *Rhizostoma pulmo* and *Rhopilema nomadica*. The species with the highest no. of reports was *Mnemiopsis leidyi* and the 2nd most recorded species was *Cassiopea andromeda* with 24 and 12 reports, in total, respectively. In 2012, the highest no. of jellyfish species was recorded (7 species), and it was also the year with the most reports made (38).The highest no. of species and reports were observed in August, with 8 species and 17 reports, respectively. Three large blooms (more than 1000 individuals) and three medium blooms were observed (100-1000 individuals), in the total duration of the study. Two large blooms and one medium bloom of *Mnemiopsis leidyi* occurred in Larnaca and Limassol in 2012. A large bloom of *Cassiopea andromeda* occurred in Kato Pyrgos and a medium bloom in Paphos in 2013, whereas a medium bloom of *Aurelia aurita* was recorded in Ammochostos in 2015.

4. Conclusions/Discussion

Anthropogenic impacts play an important role in the increasing occurrence of jellyfish blooms. Climate change, introduction of non-indigenous species, construction of breakwaters, overfishing and eutrophication, all affect the increase of jellyfish populations to varying degrees (Acevedo et al., 2013).The main geographical differentiation in the distribution of the observed jellyfish is that the highest no. of observations of jellyfish came from the east coast of Cyprus (Ammochostos and Larnaca) in comparison with the west coast (Paphos and Limassol). This might be due to higher temperatures recorded in the east coast. This study gives the first insights for the abundance of jellyfish in Cyprus that will be used for the investigation of the parameters that affect the jellyfish populations.

5. Acknowledgements

Many thanks to the citizens of Cyprus who actively participated in this study. This work has been done in the frame of the CIESM Jellywatch project.

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A website platform for uploading data from a new systematic jellyfish monitoring system in the Balearic Islands: a joint science-society approach.

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Abstract

The impact of jellyfish swarms in the Mediterranean coasts is a well-known repetitive phenomena; However, there is a gap of systematic and periodic data on jellyfish occurrence in beaches. These data are needed to understand the inter-annual variability of the episodes and its potential relation to the variability of environmental conditions. We present a joint stakeholder-scientist pilot strategy to address this gap focused in the Balearic Island. The jellyfish observations network was established with qualified and trained personnel, monitoring at high spatial and temporal resolution in different types of coastal areas. The resulting database will allow progress towards a solid understanding of the episodes and the implementation of appropriate knowledge-based future mitigation actions.
Keywords: joint stakeholder-scientist, Balearic Sea

1. Introduction

Jellyfish swarms in the Mediterranean coasts are a recurrent phenomenon of high scientific interest (Kogovsek et al., 2010) and with relevant implications at the touristic and socio-economic level (Kontogianni and Emmanouilides, 2014; Prieto et al., 2015). There is however a gap of systematic and periodic data on jellyfish occurrence in beaches. These data can help to understand the inter-annual variability of the episodes and its potential relation with the variability of environmental conditions. Joint strategies with tools available to scientist, administration, policy makers and stakeholders can optimize the cost of obtaining these *in situ* data and the benefit achieved from its scientific analysis.

2. Materials and methods

A joint stakeholder-scientist pilot strategy was designed and tested in the Balearic Island during Summer 2014 (starting July 1st) and beyond, in the frame of SOCIB activities of the Strategic Issues and Applications Division (Tintoré et al., 2013). In the second year, 2015, it was operative from January 1st. The system involved the regional fisheries, environmental and emergency administrations, charter associations as well as CSIC institutes and SOCIB. For the first time, a routine and systematic program of surveillance of jellyfish observations was established with qualified and trained personnel, monitoring at high spatial and temporal resolution in three different types of coastal areas: the marine reserves, the coastal waters -around 1 mile offshore-, and the beaches. The system includes a web platform and an associated database that compiles the daily sightings in 5 Marine Protected Areas (with several observation sites each by DG Fisheries personnel), in 33 routes (with 66 sites) from the coastal area boat cleaning services from DG Water Quality and at 120 beaches where monitoring was carried out by lifeguards from the DG Emergencies. All observations were performed following established protocols to obtain a systematic, periodic, routine monitoring. The application allows the filtering per location or period. A "heat map" showing where is the highest abundance of jellyfish is also available. Right now the access is restricted to participating institutions and each user is identified. The entire dataset that is being accumulated will be available for download by the users.

3. Result

The total number of observations registered on the website during both years is 34.369, although from all those observations only in 1754 cases were jellyfish observed. In the first pilot year, a total of 799 positive jellyfish sightings were registered. In that year, the most abundant species was *Pelagia noctiluca* (513), followed by *Cotylorhiza tuberculata* (119) and *Rhizostoma pulmo* (71). During the second year, 2015, a total of 955 jellyfish sightings were reported. In 2015, again the most abundant species was *Pelagia noctiluca* (616). The rest of the jellyfish species were one order of magnitude lower, being *Velella velella* (89), *Cotylorhiza tuberculata* (76) and *Rhizostoma pulmo* (52). The most active users are the beach emergency staff (with 25.409 observations), followed by the workers from the routes of the boat cleaning services (8700) and from the marine protected areas (260). The database is being created to incorporate information from meteorology and oceanography later on, in order to advance in the understanding of the links among the jellyfish swarms in the shore and the different scales of variability at which they are affected.

4. Conclusions/Discussion

In a pioneer effort, several governmental services from the Balearic Islands have worked together with scientists and upload jellyfish observations in real time, establishing a new database generated under scientific standards to allow a solid understanding of the episodes and the implementation of appropriate knowledge-based future mitigation actions.

5. Acknowledgements

We acknowledge both PERSEUS (FP7-287600) and SOCIB for the financial support.

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Oceanographic data assembled for a large regional project (PERSEUS)

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Abstract

Physical, geochemical and biological oceanographic data, which were acquired and submitted in the framework of the PERSEUS project, were uploaded into the project-oriented database (DB). The DB also contains the bulk of the available historical data for the Southern European Seas (SES). All the data in the DB passed quality control (QC) and have a metadata that conforms to SeaDataNet (SDN) standards. An on-line interface allows for flexible data selection and download. Up to 250 cruises can be selected for download in a single ODV collection. Up to 100,000 selected casts can be downloaded as a single MS ACCESS file with an automatic harmonization of parameters and units. The PERSEUS data have also been made available through Copernicus In Situ TAC (INSTAC) center and are expected to mainly serve the needs of operational oceanography.

Keywords: Oceanographic Data Base, PERSEUS data collection, SeaDataNet, Copernicus

1. Introduction

A large part of the success of PERSEUS depends on the ability of project partners to have fast and simple access to the historical collection of oceanographic data. This collection has been extended continually throughout the project's duration, thanks to the efforts of the partners and the collaborative projects. Historical SES data were inherited from the SESAME project (2006-2010). Significant advances in the development of SDN standards provided much needed framework for reorganizing the SESAME DB output (Gertman et al., 2010) in order to harmonize the wide spectre of parameters, methods and units. An additional improvement to the SESAME project DB was the establishment of data exchange agreements and protocols between the project and other EU projects that perform observations and collect data in the SES (MyOcean (now Copernicus), FixO^3). As a result, most of the data collected by autonomous platforms, such as Floats, Gliders and Moorings, have been imported into the PERSEUS DB by the Coriolis data centre, which made the data available to Copernicus as well.

2. Data flow

The web interface of the PERSEUS DB - http://isramar.ocean.org.il/perseus_data - (Gertman et al., 2013) supports on-line import and QC of new data in an ODV format. The identification of parameters in the PERSEUS system is based completely on the Common Vocabularies that were introduced as standard terms by SeaDataNet: P01 (parameter usage vocabulary), P06 (data storage units) and P02 (parameter discovery vocabulary). Typically, a dataset submitted by project partners contains data acquired by a single instrument (CTD, Bottles, Plankton Net, Box Core) within one cruise. The import of data from autonomous platforms (Floats, Gliders, and Moorings) is carried out periodically through the use of a dedicated index, which is generated by the Coriolis centre in order to identify datasets relevant to the PERSEUS DB (Petit De La Villeon et al., 2015). GIS like on-line user interface provides flexible data selection and an analysis of metadata. The system supports two ways to export and download selected data: 1) A single cruise or an aggregate of cruises (up to 250 cruises) in an ODV format (parameters and units are the same as in the submitted dataset); 2) An aggregate of cruises (up to 100,000 casts) in a MS ACCESS format (the harmonization of parameters and units is optional). A dedicated software developed in the PERSEUS framework is available for mapping and other visualization of the data stored in the MS ACCESS DB files. An additional application was developed for the quality control of the data in the ODV files. This software can be used in a dialog mode for quality checking any of the ODV data, or in automatic mode during the on-line import of datasets in the DB.

3. Data inventory

At the end of October/2015 the PERSEUS Cast DB contained 340,149 casts with 351 different oceanographic parameters (in terms of P01 vocabulary). The total amount of casts increased by 49% compared to the amount of casts assembled until end 2009 in the SESAME Cast DB. PERSEUS partners from 21 institutions submitted 11,328 CTD and Bottle (Rosette) casts (Fig. 1) acquired by research vessels during oceanographic cruises.

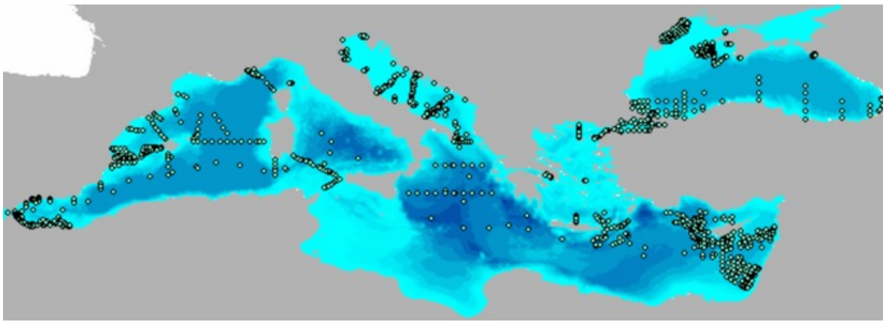

Fig. 1. *The location of CTD and Bottle (Rosette) casts performed by PERSEUS partners using research vessels and submitted directly to the PERSEUS Cast DB.*

A larger volume of casts (32900) was acquired by autonomous platforms like Argo Floats and Gliders (Fig. 2) since 01/01/2010. These data have been processed in Coriolis and a dedicated to PERSEUS index to the data was generated. About 60% of these data are copied already in the PERSEUS DB.

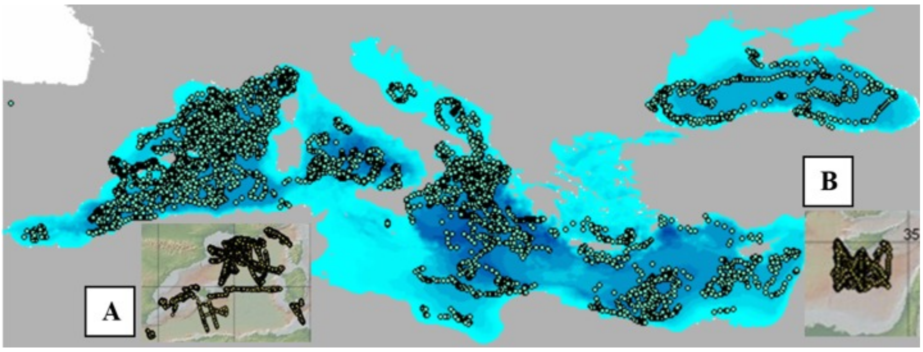

Fig. 2. *The location of Argo Floats casts and Gliders casts (insertions A,B) acquired since 01/01/2010 and partly transferred to the PERSEUS Cast DB according to the PERSEUS index from Coriolis Centre. The submission of new data by PERSEUS partners and the transfer of recently acquired data from the Coriolis Centre will be underway until the end of 2015.*

4. Conclusions

The ocean data management facilities available at European level have been used in complement each other. The PERSEUS DB (inherited historical SES data of the SESAME project) acts as the main database and hosts the final repository of the PERSEUS dataset. The data have been also submitted to the Copernicus Marine Service (INSTAC In Situ Thematic Assembly Centre) each time it was relevant. Finally the data are also available through SeaDataNet which is the main gateway for EMoDnet. EMoDnet has the capacity to produced added value products using data from various project and in particular from PERSEUS.

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Towards coordinated marine monitoring for MSFD in Mediterranean and Black Sea.

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Abstract

IRIS-SES workplan for MSFD joint monitoring proposals started with the collection of monitoring programs from Mediterranean and Black Seas, created an open access inventory and incorporated an assessment of pressures and international legislation. This information was used to create raster maps of MSFD descriptors and to identify spatially and temporarily monitoring gaps. The tools produced, a GIS tool for eutrophication, contaminants and fisheries unified for both basins and a decision making tool (DeCyDe-4-IRIS), aim to support decision makers for effective local/regional monitoring and to implement measures. Finally, IRIS-SES worked towards cost-effective proposals for joint monitoring systems.

Keywords: meta-databases, tools, joint monitoring

1. Introduction

In order to facilitate the international coordination of monitoring tasks related to MSFD, DG ENV launched a call asking for projects, which should develop integrated monitoring strategies in selected pilot regions, based on existing sampling across various disciplines and scope the potential for joint programs (within and between Member States). These pilot projects demonstrated a practical way, in which current effort could be redeployed to more efficiently use of existing resources, and thus promote resource efficiency. To achieve these objectives, the IRIS-SES project “INtegrated Regional Monitoring Implementation Strategy in the South European Seas”, was funded, with the main aim to develop a new concept and decision-making tools for integrated environmental monitoring for the MSFD and other environmental legislation, and to support management of human activities and their effects in EU marine waters, in selected pilot regions, in the Mediterranean and Black Seas.

2. Materials and methods

IRIS-SES work was developed across four interlinked activities: (i) Cataloguing and analysis of monitoring programs carried out in the framework of European/Regional/ National legislation, in relation to MSFD requirements, along with analysis of pressures (ii) assessment of the multi-disciplinary and multi-state monitoring programs towards the identification of emerging monitoring needs and gaps and integration among descriptors and indicators; (iii) development and integration of Intelligent Tools; and iv) developing plans for Joint Monitoring Programs in the Mediterranean and Black Sea regions to meet the MSFD requirements, based on the optimization and adaptation of ongoing monitoring programs. IRIS-SES collaborated closely with MSFD related Projects and the two Regional Sea Conventions of the area (UNEP/MAP and BSC). A series of stakeholders’ workshops took place in both basins to discuss the project’s products/tools and have the necessary feedback for the optimization of the project outcomes to the needs of national and international stakeholders.

3. Results/Discussion

A catalogue of existing information on national/international marine monitoring programs in the Mediterranean and Black Seas (seven MSs: Romania, Bulgaria, Greece, Cyprus, Italy, Spain and Croatia and Turkey) was compiled to produce: (i) the Inventory/Meta-database of the programs (electronic form), grouped according to descriptors and the meta-database in ACCESS (.mdbb), compatible with larger oceanographic/environmental databases and through the use of INSPIRE and SeaDataNet standards and (ii) an analysis of pressures (with future projections) and an inventory and critical assessment of international/regional legislation. A report on spatial/temporal variability on water column and seabed habitats indicators was then produced along with a gap analysis on the existing data on spatial and temporal extend of marine monitoring, presented in the form of raster maps of MSFD descriptors to identify monitoring needs. All the above information was integrated to produce a GIS planning tool using background features/main geographic layers leading to the development of Environmental Status criteria and the adaptation of GIS tools for the D3, D5, D8 & D9 descriptors unified for Mediterranean and Black Sea addressed to scientists, decision makers and non-experts. The DeCyDe-4-IRIS tool (.xls), was developed too, an adaptable, site- and case-specific decision-support method, including a country-specific self-assessment tool to support decision makers to design effective local/regional monitoring plans and implementable abatement measures. Finally, Proposals for Joint Monitoring Plans were put forward taking into account the results from all activities and conclusions from the pilot feasibility studies that could be adopted by the RSCs (UNEP/MAP and BSC) and the EU MSs. Finally, inter-regional cooperation has been another important aspect of IRIS-SES, mainly with the two RSCs, as well as the other two pilot projects (BALSAM for Baltic Sea and JMP NS/CS for North and Celtic Sea), as synergies and similarities have actively been sought between the European sea regions and led to a joint 'Towards coordinated monitoring in the European Regional Seas' DG ENV sponsored workshop. All outcomes and tools are available online also for the decision-makers and stakeholders (http://iris-ses.eu/category/outreach/results-outreach/).

4. Acknowledgements

The IRIS-SES project was co-funded by the EC-DG ENV, Grant Agreement: 07.0335/659540/SUB/C. Partners: HCMR (coordinator), IEO, Univ. of Salento, NIMRD, IO-BAS, TUBITAK, Plan Blue, Univ. of Athens, ISOTECH.

Marine environmental targets linked to regional management schemes based on indicators developed for the Mediterranean Sea – The MERMAID Project

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Abstract

MERMAID is a SEASERA project (2013-2015), acting in three case study areas, the Gulf of Lions (France), Saronikos gulf (Greece) and the Cilician basin (Turkey). Its main objective is to provide additional scientific understanding for assessing GES in a coherent and holistic manner by a state of the art methodology that has been developed and applied in the three under study areas, and to link the management measures designed for these areas to the targets set up for the achievement of GES. Five MSFD descriptors, D3, D7, D8, D9 and D10, are considered.

Keywords: Environmental Targets, GES, MSFD

1. Introduction

The increasing pressure on the marine environment by human activities has led the EU to adopt the Integrated Maritime Policy and the Marine Strategy Framework Directive (MSFD). The MSFD provides a comprehensive framework for the protection of the marine environment, which requires the adoption of a programme of measures at national level. In this context, MERMAID was designed to improve our knowledge on pressures arising by fishing activities (D3), chemical contaminants (D8 and D9) and marine litter (D10) identified as major threats for the Mediterranean ecosystem.

2. Materials and methods

The scientific objectives of MERMAID are (a) to contribute to a more thorough assessment of the environmental quality of the Mediterranean sub-regions; (b) to review the current knowledge, to identify data gaps and to propose appropriate monitoring and methodological approaches; (c) to set SMART (Specific, Measurable, Achievable, Realistic, Traceable) environmental objectives that will contribute further to define the Good Environmental Status (GES); and (d) to identify the links between the established targets and the management measures, in three study areas, the Gulf of Lions (France), Saronikos gulf (Greece) and the Cilician basin (Turkey). The geographic scales were chosen to ensure that local impacts remain detectable, reflecting pressure-response relationships and thereby inform measures (HELCOM, 2011).

3. Results / Discussion

Typologies/families of pressure

ressures in the study areas: Typologies/families of pressures have been constructed according to key parameters including human activities and natural inputs in the study areas. The DPSIR approach was used in the process (Cormier et al. 2013). Preliminary link between pressure typology and pressure indicators was built, leading to the identification of missing links. Main threats were listed and ranked by importance according to a scoring procedure weighing their impact on the respective descriptor on the basis of existing knowledge and through expert judgment. Environmental quality status has been assessed through aggregation of the information derived from single indicators to the descriptor level on the basis of a decision tree process, taking into account the magnitude of impacts each indicator reflects on specific ecosystem properties.

Definition of GES and proposal or adaptation of targets towards its achievement: Considering already existing operational objectives for achieving GES, through close collaboration with key stakeholders and policy-makers appropriate adaptations have been made where necessary, aiming to Specific, Measurable, Achievable, Realistic, Traceable (SMART) objectives, in all three MERMAID case studies. These objectives were linked with properties reflected by each indicator under the selected Descriptors. Deviations between current state and GES have been evaluated. Prioritization of those considered as "hot spots" compromising hence attaining GES were made through the stakeholders' consultation.

Monitoring activities: The existing monitoring programmes and observational systems in each study area were reviewed and the major data gaps have been identified. The review revealed that the major data gaps are mostly related to marine litter (D10) especially in Saronikos Gulf and the Cilician basin, leading to relevant pilot studies.

Linking targets and management measures: The EU MSFD sets quite demanding requirements with reference to the evaluation of the proposed program of measures using cost-benefit or cost-effectiveness analyses. Aiming at bridging this gap in marine policy and decision-making, a cost-effectiveness ranking algorithm, named MeTaLi, has been developed. It provides a simple, transparent and straight forward framework to evaluate alternative policy measures for achieving or maintaining GES in EU marine waters.

4. Acknowledgements

The research was supported by the GSRT, Greece, the ANR, France, and TUBITAK, Turkey, through the MERMAID project "Marine Environmental Targets linked to Regional Management Schemes based on Indicators developed for the Mediterranean" (FP7 ERANET 12SEAS-12-C1).

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Assesment of the environmental status of the coastal zone of the NE Black Sea: Application of the MSFD criteria

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Abstract

Based on the data obtained from multi-disciplinary monitoring fulfilled in 2005-14, we evaluated the current status of the coastal pelagic system in the NE Black Sea using also the criteria established by the MSFD for its assessment. Long-term changes in nutrient concentration and ratios, biomass and composition of phyto- and zooplankton are presented here as well as the trends in biomass of non-indigenous ctenophores and their impact on mesozooplankton. The current state of the area was assessed as quite stable and “good”, though a tendency of biomass decrease was observed and a shift in the taxonomic composition of phyto- and zooplankton.

Keywords: nutrients, phytoplankton, zooplankton, gelatinous top-predators

1. Introduction

In the present study, an attempt was made to evaluate the current status of the coastal zone in the NE Black Sea based on some descriptors of Good Environmental Status (GES) developed by the Marine Strategy Framework Directive (2008/56/EC) (MSFD). The following criteria and indicators were used: nutrient concentration and ratios; shift in floristic/faunistic composition; biomass trends of functionally important selected groups (phytoplankton and zooplankton); trends in abundance of NIS and impacts of NIS at the level of species abundance.

2. Materials and methods

Sampling was performed at the mid-shelf (50m bottom depth) in the NE Black Sea off Gelendzhik (44°31.8’ N, 37°59.2’ E). Zooplankton was collected monthly from March-April to October-November in 2005-2014. Nutrients and phytoplankton were analyzed twice per season in 2007-2009 and 2012-2014. Mesozooplankton samples were taken with a Juday net (0.1 m^2 mouth area, 180 mm mesh size). Gelatinous macrozooplankton was collected with a conical net (0.5 m^2 mouth area, 500 mm mesh size). Phytoplankton and nutrient samples were collected with Niskin bottles at depths of 1, 10, 20, and 50m. The nutrient analyses was carried out using the standard methods (Grasshoff et al., 1999). Phytoplankton cell carbon content was calculated based on the carbon:volume relationship (Menden-Deuer and Lessard, 2000).

3. Results

Annual average values of Si and DIN concentrations did not virtually change during the last eight years while PO_4 concentrations decreased noticeable. In 2013-14, the DIN:P ratios were higher than the theoretical Redfield’s value indicating phosphorus limitation. The ratios of Si:DIN and Si:P were above the theoretical values suggesting the lack of silicate limitation relative to inorganic nitrogen and phosphorus.

In 2012-14, phytoplankton carbon biomass was substantially lower than in 2007-09 mainly due to the decrease of diatom biomass. The average values of diatom biomass for the three years decreased from 18.5±8.2 mg C/m^3 in 2007-09 to 2.5±1.4 mg C/m^3 to 2012-14. The share of diatoms in the total phytoplankton biomass decreased from 38-82% to 8-22%.

A noticeable decrease in the total mesozooplankton biomass was observed in 2012-14 as compared with the previous years, mainly due to the reduction of plankton herbivores. Zooplankton composition did not show any significant interannual changes except in 2011 when the *Noctiluca scintillans* population formed 25% of the total carbon biomass and in 2013 when characterized by almost total lack of cladocerans.

Medusas always dominated the assemblage of gelatinous predators making up 50-90% of the total biomass. Over the last decade, biomass of *M. leidyi* tended to decrease while biomass of *A. aurita* increased. The share of NIS to the total gelatinous predator biomass fell significantly from 37% in 2005-09 to 11% in 2010-14 (*t*-test, $p<0.01$). Note that the share of *M. leidyi* reached 72-74% of the total carbon biomass of the gelatinous predators in 1989-90.

Pair-wise correlations between the annual average biomass of gelatinous predators and mesozooplankton computed over the period of 2005-2014 demonstrated no or negligible impacts of these top-predators on mesozooplankton.

4. Conclusion

Application of the MSFD criteria for the evaluation of the current state of the shelf ecosystem off Gelendzhik (NE Black Sea) proves the assessment of its environmental status as "good" and quite stable during the last decade, in this area.. The nutrient concentrations and ratios do not exceed practically the inherent levels, suggesting the minimal pressure of human-induced eutrophication in the area. Generally, phyto- and zooplankton composition and biomass remain at the high (compare to the 1990s) stable level. The population of non-indigenous ctenophore *Mnemiopsis leidyi* tends to decrease in the last decade and its impact on zooplankton species is minimized. Some concern is risen by some negative signals observed in the last two years which are probably connected with the direct and indirect effect of warming of the sea, namely the reduced phosphate concentration leading to the decrease in diatom biomass which in its turn negatively affects the biomass of herbivorous zooplankton. So far these changes might be considered as year-to-year fluctuations, but if this tendency remains, one may expect a significant shift in the structure and function of the coastal ecosystem.

5. Acknowledgements

This work was partially funded by the EC FP7 PERSEUS Project (Grant Agr. 287600) Monitoring program was funded by the Russian Ministry of Education and Science (Agr. №14.604.21.0044, Identifier - RFMEFI60414X0044).

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

From WFD to MSFD and from the Coast to the high seas: Study of the suitability and performance of status indicators

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Abstract
In this work, indicators of Descriptors D1, D5, D6 and D7 that have been used for the assessment of ecological and environmental status in Greek coastal areas (Eastern Mediterranean) were applied in the offshore areas of the N. Aegean Sea in order to test their suitability over the two water categories and Directives (WFD-MSFD). Results showed that the indices performed sufficiently in both water categories with the condition that suitable reference values and interpretation scales are used.
Keywords: Descriptors, trophic status, multimetric Bentix

1. Introduction

In general and according to Crise et al. (2015), there is a good agreement on the pressures identified in open seas and those active in coastal systems, with the exception of eutrophication (D5) and hydrographic conditions (D7). These two descriptors are not strictly applicable to the oligotrophic open seas of Eastern Mediterranean, thus, other pressures that are relevant to trophic conditions and to the circulation of the open seas should be considered. On the other hand, the transition from the WFD to the MSFD should be seamless, without any conflicts in the assessment, and therefore, a starting base is necessary (Borja *et al.,* 2010). Status indicators pertaining to Descriptors D1, D5, D6 and D7 were applied in the high seas areas of the Aegean Sea in order to test their performance over the two Directives' jurisdiction zones.

2. Materials and methods

The status indices applied on the Perseus AEGEX datasets were for: D1, D6: the Bentix multimetric index (Simboura et al., 2015 using specific reference values and scales for offshore benthic ecotypes; D5: Eutrophication Index (E.I.) (Primpas et al., 2010), TRIX trophic indices (Primpas et al., 2011); D7: Factor Analysis (FA) physicochemical status index (Bald et al., 2005), using offshore waters reference conditions. The indices for D5 and D7 were applied for (a) the whole water column and (b) the euphotic zone. Their performance was compared with the results of their application over WFD coastal monitoring datasets.

3. Results

On average, the assessment by E.I. and TRIX resulted into GOOD and HIGH trophic status respectively for the euphotic zone and into GOOD status for both TRIX and E.I. for the whole water column. This finding is in accordance with the results from the assessment of Greek coastal stations reporting E.I. as a too sensitive or stringent, index suggesting a future modification of the high to good boundary (Pavlidou et al., 2015). When data from the whole water column were used, the trophic status showed a certain downgrade related to the higher concentrations of nutrients in the deeper layers. Based on FA method, the physicochemical status was on average GOOD, for both the euphotic zone and the whole water column data treatment. The reference conditions used for FA were selected following the characteristics of the area. The multimetric benthic communities' status index assessed all stations as in GOOD status, matching with the trophic and physicochemical status results, with the exception of the closest to the mainland coast station assessed as in MODERATE status (related to deep layer organic nutrients concentrations). Due to the extreme oligotrophy of the deep Aegean environment, the use of a natural stressed areas' scale is suggested for the interpretation of the status by multimetric Bentix in the bathyal.

4. Conclusions/Discussion

Results showed that the indices performed sufficiently in both water categories with the condition that suitable reference values and interpretation scales are used. E.I seems to be a more sensitive index, but a modification of the high to good boundary of E.I. is needed. The trophic status of the study area is mainly related to the Black Sea Water (BSW) outflowing from the Dardanelles, the biogeochemical processes in the euphotic zone and influence from the coast.

5. Acknowledgements

This work was conducted within the framework of PERSEUS Project, WP1.

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Assessing the power of size spectrum analysis in estimating the pelagic ecosystem status of Mediterranean areas over a wide range of combined pressures.

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Abstract

The present work is a first compilation of Normalized Biomass Size Spectrum (NB-SS) data acquired from a wide range of pelagic organisms from various locations with different environmental status, in the Mediterranean Sea. It offers an initial evaluation of the NB-SS as an index for the entire pelagic ecosystem status, when under the impact of combined pressures.
Keywords: biomass, plankton, index.

1. Introduction

Biomass size spectra have been used to design ecosystem indicators for many different processes (Gómez-Canchong et al., 2013). The aim of the present study was to access the impact of combined pressures over a broad range of pelagic organisms and locations in NE and NW Mediterranean with different ecological status.

2. Materials and methods

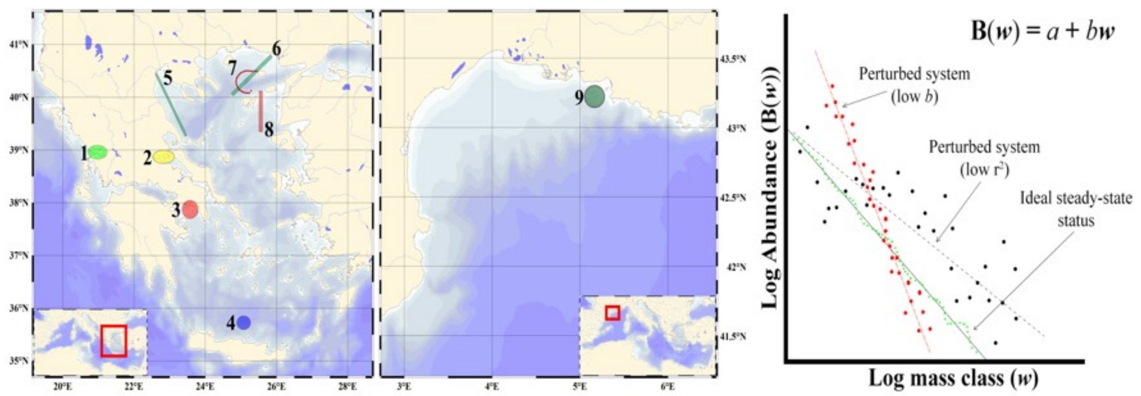

Fig.1 *Map of the various areas used in the present study (left) and NB-SS examples (right).*

Data were collected in several areas (Fig. 1). Pico-, nano- and micro- plankton was collected with Niskin bottles, zooplankton with different mesh size nets and small pelagic fishes with pelagic trawls. Sediment traps were used to measure C fluxes (area 6). Lab OPC was used to count micro- and meso- plankton sizes (area 9). The size range of pelagic organisms collected varied with location (Table 1). Size data were converted to C biomass and used to construct the NB-SS.

3. Results and Discussion

Table 1 *MSFD Descriptor criteria met by the NB-SS per area of study. G.: Gulf; Isl.: Island; ST: station;*

	Area	Organism range	Conclusion from NB-SS characteristics	MSFD
1 2	Amvrakikos G. (3 ST) Maliakos G. (4 ST)	mesozooplankton	Plankton instability at enclosed coastal areas ***missing classes,*** R^2 ***< 0.95, b < -1.3***	D1, D4, D5
3	Saronikos G. (3 ST) Elefsina Bay (3 ST)	bacteria to small pelagic fishes	Hypoxia effect on plankton ***b*** decreases by ***0.13*** under hypoxic conditions	D1, D3, D4, D5
4	Open Cretan Sea (1 ST)	micro- to meso-zooplankton	Plankton stability at open oligotrophic areas Low variability of ***b ~ -1*** & and R^2 ***> 0.98***	D1, D4
5 6	Thermaikos G. to Skopelos Isl. (5 ST) NE to SW Thracian Sea	mesozooplankton	Plankton instability at shallower stations ~ ***b < -1.3*** & R^2 ***<0.95***	D1, D4
7	Between Samothraki and Lemnos Isl. (5 ST)	bacteria to mesozooplankton	Variability of Carbon export ***b*** correlated to C vertical flux (sediment trap) (Frangoulis et al. 2010)	D1, D4
8	E of Lemnos Isl. to N of Lesbos Isl. (3 ST)	micro- to macrozooplankton	Instability during bloom especially in less oligotrophic waters ***b < -1.1*** & R^2 ***< 0.98***	D1, D4
9	G. of Lions (1 ST)	meso- plankton	NBSS model for linking Lower-Higher trophic levels (Zhou et al. 2010)	D1, D4

The NB-SS is a valuable tool for evaluating the effects of combined pressures on ecosystem status. It can be used for the entire pelagic ecosystem and for comparison between different areas.

5. Acknowledgements

This work was partly funded by EU IP Project FP7 – PERSEUS (Grant Agreement No 287600).

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The factors and opinions that impact the writing of an action plan for Maltese sharks.

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Abstract
The aim of this study was to look into stakeholder opinions to assist bridge the gaps between research done on sharks and the writing of an action plan. The quantitative section gives background information on the Maltese shark fishery. The qualitative portion was based on interviews carried out with stakeholders. Results showed discrepancies between landing datasets as well as species nomenclature. It was concluded that a standardized set of data variables, a consistent data collection routine, a standard list of Maltese nomenclature, and open public education and discussions are required before an action plan can be written.
Keywords: elasmobranchs, stakeholder, Mediterranean, management, policy

1. Introduction

Recently, interest in shark conservation has increased. Sharks are known to be vulnerable due to their 'k-selected' life cycle characteristics. A large portion of sharks are landed as bycatch from fisheries that are meant for more economically valuable fish species. However, they are seen as an alternative form of income for fishermen. One of the main issues with the management of sharks as bycatch is the lack of well recorded and accurate landing data. The Maltese fishery is known as a small-scale, artisanal fishery and roughly 65% of the shark species recorded in the Mediterranean visit the archipelago. To-date, no action plan for sharks has been written for Malta. This study set out to look into stakeholder opinions to assist bridge the knowledge gaps between research done on Maltese sharks and the writing of an action plan.

2. Materials and methods

The study was carried out using a mixed approach meaning; elements of both quantitative and qualitative research were applied. The quantitative section of research gives background information on the Maltese shark fishery. The data utilized in this section came from Sharklab landing data, as well as the EU statistical database. The qualitative portion was based on interviews carried out with various stakeholders, namely; fishermen, hawkers, NGOs and governmental entities. A list of nomenclature used for Maltese shark species was drawn up to highlight issues with the overlapping of use of the same names for different species.

3. Results

Sharklab data indicated that the most frequently caught species between 2009 and 2014 was Longnose spurdog (*S. blainvillei)* and the least frequent was the Kitefin shark (*D. licha*). Tope (*G. galeus*), Short-fin Mako (*I. oxyrinchus*) and Porbeagle (*L. nasus*) landings were frequent despite them being protected. Discrepancies between different shark landing datasets were noted. Nomenclature with the name '*Mazzola*', the phrase '*Kelb il-bahar*' and having the '*pixxi*'- prefix were found to be the names which were used to refer to the most species and therefore had the most issues. Fishermen and Hawkers believed that the main problems with the Maltese shark fishery were; declining shark populations and strict regulations. The most popular solution amid the fishermen and hawkers is the creation of no fishing zones to protect shark stocks. The common problems put forward during interviews were the lack of; accurate landing data, public awareness and perception. Frequently presented solutions during the interviews were the increase in; accurate data collection schemes, public education and stakeholder involvement.

4. Conclusions/Discussion

It was concluded that once the following were implemented and put together: a standardised set of data variables (species, length, weight, sex, maturity, gear, price and date) and units; a consistent data collection routine; a standard list of Maltese nomenclature; education programmes and open public discussions; that the writing of a viable action plan could be possible. Prioritization of vulnerable species will be the main challenge that will need to be overcome.

5. Acknowledgements

This poster represents the work done for my MSc thesis at Trinity College, Dublin under the supervision of Prof Wilson and Dr Nolan. Data used were given to author by Sharklab Malta.

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A stepwise guide for drafting adaptive marine policies

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Abstract

The PERSEUS project provides scientific advice to policy makers in the Southern European Seas who are in the process of developing programmes of measures to meet the objectives of the Marine Strategy Framework Directive (MSFD) aimed at achieving and maintaining the Good Environmental Status (GES) of marine waters. This paper presents the PERSEUS Adaptive Marine Policy Toolbox; a 5-Step approach for adaptive policy making, designed in collaboration with stakeholders to actively support their adaptive policy making. For each of the 5 steps, tools which can be used to support implementation are presented.

Keywords: tools, adaptive policy making

1. Introduction

The work presented in this paper is part of the PERSEUS project work package 6 which developed an Adaptive Marine Policy (AMP) Toolbox. In order to enhance the uptake and use of this toolbox, this paper explains the 5 steps which can be taken by policy-makers in the Mediterranean and Black Sea, who aim to develop adaptive policies. For each step it is investigated which methods and tools are available to support implementation.

2. Adaptive Policy Making and the MSFD

The MSFD encourages Member States to take steps to preserve and protect their marine waters and provides a framework for action. In this regard, the individual Member States are responsible for the policy making by developing a programme of measures to achieve the objectives set by the MSFD. Member States are also obliged to provide periodic reports in defined time periods to the European Commission (EC), meaning a pre-determined policy cycle already exists (see European Commission website).

3. The PERSEUS Adaptive Marine Policy Toolbox

The PERSEUS Adaptive Marine Policy Toolbox[1] demonstrates that it is possible to increase the adaptiveness and flexibility of the MSFD policy cycle by incorporating certain principles and methodologies which have been successfully applied in other policy fields. The following tools can be used to support implementation:

- Step 1 – Setting the scene: Stakeholder mapping/stakeholder analysis, Multi-stakeholder deliberation, DPSIR Framework, Scenario development;
- Step 2 – Assembling basic policy: Multi-criteria analysis, prioritization tools, public participation tools;
- Step 3 – Making policy robust: Tools for making and improving scenarios or storylines, Multi-Cases Tool, Multiple Criteria Decision Analysis;
- Step 4 – Implement the strategy: Tools for facilitating monitoring and participation at different levels; project management tools; and tools for the continuous control of policy implementation;
- Step 5 – Evaluate and adjust policies: Tools facilitating the communication of scientific knowledge and the use of scientific information in deliberative processes, Project management tools, Tools and strategies for monitoring of key-indicators, Tools and strategies for evaluations of the performance of potential policy adjustments.

4. Conclusions

There is a lack of guiding tools to support adaptive management in the marine environment. Many tools are based on one main driver (e.g. FAO toolbox for fisheries) or on implementing management measures (e.g. MPA). Using the PERSEUS AMP Toolbox will make the policy more adaptive by changing the way it is designed and implemented and assuring continuous, targeted monitoring and evaluation. The PERSEUS AMP Toolbox addresses the integrated nature of the MSFD. In order to guide and support the implementation of the framework, together with stakeholders, a toolbox with an online interface was created (see also abstracts by Garmendia et al. 2015 and Breil et al. 2015).

5. Acknowledgements

This work is part of the research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, http://www.perseus-net.eu Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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[1] *The tool box can be found at: http://www.perseus-net.eu/en/about_the_apf_toolbox/index.html*

Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Identification and selection of tools and methods for developing adaptive marine policies in the Mediterranean and Black Seas

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Abstract

Marine ecosystems are complex and dynamic systems asking for the implementation of adaptive policies able to face changes over time. Within the PERSEUS project a step-wise process for selecting tools accounting for social, economic and environmental issues in marine areas was performed in order to identify the best ones for sustaining the development and implementation of adaptive policies. Selected tools were included in the 'Database of tools and methods' of the Adaptive Marine Policy Tool Box (AMP TB), designed for supporting policy makers in the interactive steps of the Adaptive Policy Framework (APF).
Keywords: Adaptive management, Policy-making, MSFD, Adaptive Marine Policy Toolbox.

1. Introduction

The design and implementation of sustainable plans and policies for coasts and seas requires a new paradigm for policy-making accounting for multiple issues (e.g. marine litter, eutrophication) as well as complex natural ecosystems' and socio economic dynamics (EP, 2008). Accordingly, it becomes urgent to design and implement new adaptive policies capable of facing situations characterized by high uncertainty and complexity. New tools and methods are therefore needed to sustain policy makers in robust decision-making by integrating multiple scenarios from climate, ocean and physical models with socio-economic data. Based on a review of over 160 tools available in the literature or on the web, 43 tools were selected to implement the interactive steps of the APF and then employed in the 'Database of tools and methods' of the AMP TB, in order to provide policy makers with a set of tools for designing and implementing adaptive policies in marine areas.

2. Materials and methods

A step-wise process for reviewing, scoring, ranking and selecting existing tools, suitable for supporting the APF was performed. First of all, collected tools were described following details' attributes: (i) complete name of the tool; (ii) source/reference toolbox; (iii) link for further information; and, finally (iv) the specific use of each tool within the APF steps. Based on tools' utility, 43 "primarily useful" tools, were identified and organized according to different fields of expertise (e.g. economic tools, risk assessment tools). Finally, these 43 tools were scored and ranked against 4 criteria, namely: (i) availability, (ii) simplicity, (iii) applicability and (iv) interest, with the main aim of identifying the most useful for supporting the different steps of the APF.

3. Results

The final ranking allowed to identify tools with the highest scores (i.e. "flag-tools") representing the most valuable ones based on selected criteria and expert judgment. The process allowed excluding tools with lowest scores, often related to high cost for their purchasing or the non-availability for free. For each "flag-tool" a detailed tool page was designed in the 'Database of tools and methods', providing information to assist potential end-users selecting tools based on their specific needs and expertise.

4. Conclusions/Discussion

A review of tools was performed to populate the 'Database of tools and methods' of the AMP TB, representing a comprehensive repository of available tools for adaptive policy making in marine areas. Selected tools were discussed with stakeholders during several workshops performed in the Mediterranean and Black sea, aimed at testing and validating the efficacy of the AMP TB in real case studies characterized by different geographical features and environmental issues.

5. Acknowledgements

This work is part of the on-going research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, http://www.perseus-net.eu Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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Marine policies making for the Saronikos Gulf (Greece) a case for adaptive policy making

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Abstract

The paper describes the application of the AMP Toolbox to a policy issue in the Gulf of Saronikos (GR). Past interventions succeeded in fighting eutrophication, but new problems surge with the dominance of new species (Paracentrotus lividus) overgrazing the sea floor habitat. The application of an ecosystem based, adaptive policy framework to analyse the problem and formulate future management strategies indicates that innovative solutions could improve the status of the marine area of the Gulf of Saronikos by enlarging the approach from the protection of a single species Cystoseira spp. towards a more holistic, integrated view on the ecosystem.

Keywords: ecosystem based policies, case study.

1. Introduction

During the last decades of the 20th century, ten years after the realization of a waste water treatment plant, the PERSEUS case study area "Saronikos Gulf" had recovered from a heavy eutrophication. The re-oligotrophication, was clearly marked by the decrease in the abundance of nitrophilic green algaes. But, in parallel, there was also an increase of sea urchin populations on the rocky coasts the Gulf, that are over-grazing the brown algae populations. Direct interventions on this species (e.g. commercialization) are banned by local regulations, so alternative strategies are needed to support the improvement of the overall status of the marine ecosystem in the Gulf. These outcomes from a pressure-impact oriented approach to the eutrophication problems show that more complex approaches are needed in order to not create new problems with every new intervention. We propose an application of an ecosystem based approach for elaboration of such policy, using methods and resources of the PERSEUS Adaptive Marine Policy (AMP) Toolbox[1].

2. Methods and Strategies.

The formulation of ecosystem based strategies based on a holistic consideration of the problem, calls for new and more complex interactions to be considered. Following the stepwise approach suggested by the PERSEUS Adaptive Marine Policy toolbox, the steps of the definition of the problem, the identification of potential measures and the adoption of a robust strategy should be developed in a participative manner, involving a possibly broad range of potential actors and stakeholders in a tiered approach according to their potential function. The AMP toolbox provides guidance for the performance of activities guiding a holistic consideration of the problem (especially the DPSWR framework), towards a shared definition of the problem and identification of policy goals. It can **be**

[1] *http://www.perseus-net.eu/en/about_the_apf_toolbox/index.html*

searched for potential measures searching either for corresponding Drivers, Pressures or Impacts. A search for "fisheries" actually yields 25 examples of potential measures, two of these explicitly addressing recreational fisheries. The toolbox provides, furthermore, support for the choice of the adequate assessment method. In the case of a great variety of potential factors like those of the highly urbanized context of the Saronikos gulf, where potential welfare losses and gains entail monetary and non-monetary values, the support by a multi-criteria analysis tool might be useful as it is able to address and assess different preferences among actors. The toolbox contains a database of results from economic valuation studies which can be used as a reference for the estimation of non-market values. For the Saronikos case, this database can be used for searching information on potential (monetary) welfare losses for recreational fishermen. The third step of the policy cycle aims at making the policy robust and adaptive, taking into account existing knowledge gaps and future uncertainties (which predator is lacking, are there other reasons leading to the loss of seagrass, risk of invasive species and increasing water temperatures). This can be done considering the ecologic, economic, social and legal feasibility of the decision making mechanism for measures which allow for learning (i.e. planning for regular consultation among actors on the feasibility of the chosen strategy in relation to the availability of new monitoring data) in order to apply clear and measurable management objectives, considering also the availability of the resources required for implementation, monitoring and future correction of the strategy. This implies accurate planning for the implementation, defining responsibilities, resources and timeframes for measures and monitoring. With regards to the design of monitoring plans, the knowledge base hosted in the AMP toolbox provides a wealth of information potentially useful for supporting these decisions. Apart for this technical learning, as mentioned above, the plan should also facilitate cyclical assessment and revision of the targets, as well as the rest of the elements of the policy. Finally, the evaluation of the policy will lead to the identification of corrective actions or adjustments required to improve its effectiveness. These adjustments or actions can be performed following briefly the processes described in the second, third and fourth steps. For example, the data recorded with the monitoring plan can allow for knowledge accumulation to update and increase the confidence of the models or the future scenarios.

3. Acknowledgements

This work is part of the research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, http://www.perseus-net.eu Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

Past, Present and Future of Turkey's Marine Ecosystems in the Light of Research, Policy and Societal needs

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Abstract
This study investigated the long-term progressions in the Turkey's regional fisheries and their corresponding ecological consequences on the country's fishing grounds in the Black Sea, the Marmara Sea, the Aegean Sea and the Mediterranean Sea in relation to meeting the societal and economic needs of the country over the last four decades. Learning from the past experiences, the present study explored possible future Ecosystem Based Fisheries Management policies by utilizing a combined method of data and model based approaches. Outputs of the study would give an insight to the stakeholders for achieving and sustaining GES in the Turkey's regional seas.
Keywords: Turkey's marine capture fisheries, governmental supports, economic crises, fisheries management

1. Introduction

Fish are exploited in the four seas surrounding Turkey, the Black Sea, the Sea of Marmara, the Aegean Sea and the Mediterranean Sea. In addition to significant variations in their physical and biogeochemical characteristics, these seas house distinct fish assemblages which have been exploited by independent fishing fleets. Currently, the fisheries in all of the regional seas are subject to similar management practices except for some additional regional restrictions (Ünal and Göncüoğlu, 2010). The present study examined the past, present and future of Turkey's fisheries and its supporting marine ecosystems in the light of research, policy and societal needs by means of a combined suit of data and model based analyses.

2. Materials and methods

Fisheries contribution to food security and Gross National Production (GNP) was analysed in relation to country's ever-increasing human population from 1970 to 2014. The development of Turkey's fishing fleet; its socio-economic efficiency and economic profitability were explored in the period of 1970-2014 and correlated to the years and subsequent years of governmental subsidies implementation and economic crises. Regional fisheries and ecosystems were investigated through fisheries-based indicators (landings, number of vessels and fishers in the fleet, fishing effort and efficiency) and landings-based ecological indicators (mean trophic level, mean length, intrinsic vulnerability index, proportion of small pelagic fish). Ecopath with Ecosim (EwE) ecosystem models were set up in the regional seas and validated for the years 1990-2010. The validated models were then used to carry out forecast simulations for the 2010-2030 period in order to predict the impact of different management options on the Turkish marine ecosystems.

3. Results

Within the period of 1970-2014, fisheries contribution to Turkey's food security and economy decreased in terms of per capita fish consumption and fisheries contribution to GNP (from 7.7 kg/year and 0.44% in the 1970s to 5.4 kg/year and 0.27% in 2014 respectively). Turkey's marine capture fisheries performed a continuous growth in terms of number of vessels and fishers, and engine power and reached their highest values in 2003-2005 though landings already attained its maximum value of 623 ktons in 1988. The number of vessels and engine power of the fleet were found to be increasing in the year and/or in the following year of the governmental subsidies and the increase in the number of fishers was positive in the years of economic crises and negative in the following years of the crises. Fisheries indicators performed similar fluctuations; however, ecological indicators displayed different trends in the four regional seas. Time series of at least one of the four ecological indicators had a negative trend in each ecosystem. EwE modelling in 1990-2010 showed that higher biomass proportions were accumulated in the first and second trophic levels of the Black Sea and the Marmara Sea whereas they mostly accumulated in the third and fourth trophic levels of the food chain in the Aegean Sea and the Mediterranean Sea. Keystone analyses showed that different fish species played structuring roles in each of the four regional ecosystems and forecast simulations proposed the necessity of region specific fisheries management policies.

4. Conclusions/Discussion

Turkey's fisheries production in terms of weight and value remained limited for fulfilling the demand of the society mainly due to the rapid increase in the human population and national economy as well as the limited production capacity of the capture fisheries. The development of the over-fishing capacity despite the limited relative catch values were sustained by the supportive management applications and economic crises. Analyses highlighted that precautionary management practices that could be applied to fisheries policies are likely to prevent catastrophic fluctuations in the quality of the goods and services that the fisheries sector provides in each marine ecosystem.

5. Acknowledgements

This study was carried out with the support of TUBITAK 113Y040 DEKOYON Project, FP7 Perseus Project (Grant Agreement No. 287600) and METU-CARES / Center for Marine Ecosystems and Climate Research Project (DEKOSIM).

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Setting the scene for defining adaptive policies in marine areas: application of a risk-based approach for multi-hazard assessment in the Adriatic sea

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Abstract

Multiple human-made pressures, as well as climate change effects, are posing rising pressures on the marine ecosystems, impairing their structure and functions. A spatially explicit risk approach was developed for estimating environmental impacts posed by climate drivers in combination with local to regional anthropogenic pressure, allowing a quick scan assessment and ranking of marine targets and activities at risk. The methodology was applied to the Adriatic sea by producing a range of GIS-based maps and tabular results and therefore summarizing key risk metrics useful to set priorities in maritime spatial planning and management.
Keywords: MSFD, risk assessment, Multi-Criteria Decision Analysis, Adriatic sea, GIS maps.

1. Introduction

Europe's seas are facing increasing threats due to a range of human activities as well as changing climate conditions, compromising marine ecosystems and their services for the human wellbeing. An environmental risk-based approach should be applied in order to support the identification of areas that are more likely to be at risk of not achieving the Good Environmental Status (EP, 2008) due to multiple threats posed by natural and anthropogenic pressures. By aggregating indicators related to hazard, exposure and vulnerability with Multi Criteria Decision Analysis (MCDA) and Geographic Information Systems (GIS), this work produced, for the scenario 2000-2015, a range of spatial maps and statistics representing key risk metrics useful to define the progress toward the implementation of the Marine Strategy Framework Directive (EP, 2008) and assist stakeholders and policy-makers developing sustainable marine plans and policies.

2. Materials and methods

In order to evaluate the environmental impacts produced by human-made pressures in combination with climate-related hazards in marine areas, a risk-based approach was developed and applied in the Adriatic Sea. According to the three main pillars of risk defined by UNISDR (2009) and IPCC (2012) (i.e. hazard, exposure, and vulnerability) the approach is composed of four consecutive steps. The first phase consists of the hazard assessment which aggregates metrics and scenarios of climate, ocean, bio-geochemical and anthropic pressures (e.g. temperature and salinity variation, bottom stress) for determining potentially affected marine areas. The exposure assessment identifies and localizes key receptors that could be subject to potential losses in marine areas (e.g. seagrasses and coral and maërl beds). Subsequently, the vulnerability assessment, is aimed at evaluating the degree to which the receptors could be affected by the considered hazards, based on their specific physical and environmental features (e.g. habitat extent and typology, biodiversity indexes). Finally, the relative risk assessment combines the information about the considered hazards, exposure and vulnerabilities, in order to identify marine areas and targets at higher risk from multiple pressures.

3. Results

Results obtained for the Adriatic sea include GIS-based hazard, exposure, vulnerability and risk maps, as well as key risk indicators calculated for the selected marine receptors (e.g. extent of key habitats potentially affected by human activities or by alterations of physical and chemical parameters). These can be used as decision support tools for planners and local authorities, providing guidance and information on the current state and risks in the marine environment, thus setting the scene for the design and implementation of adaptive marine spatial plans and policies.

4. Conclusions/Discussion

The proposed risk-based methodology supports a semi-quantitative evaluation and relative ranking of areas and targets potentially affected by multiple risks in the considered marine region. The approach is flexible to be applied in different geographical regions and scenarios, to support the evaluation of both the progress toward the achievement of GES and of the potential effects of long-term climate change. The development of risk maps is part of an iterative process that is expected to be improved, as more research on environmental and anthropogenic data and drivers will becoming available.

5. Acknowledgements

This work is part of the on-going research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS, http://www.perseus-net.eu Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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Scientific Conference
"Integrated Marine Research in the Mediterranean and the Black Sea"

Analysis of pressures of the coastal and open seas in socio-economic terms in the Mediterranean and the Black Seas: Oil and Gas Transport

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Abstract

European Union's energy imports demand ought to increase in the near future. Due to this dependence, oil and gas transport are expected to increase and, both, Mediterranean and Black Seas will continue to play a key role as energy transit regions. The Perseus project carried out the 1st regional integrated assessment of the main economic uses impacting marine and costal ecosystems of the Mediterranean and Black Seas. This poster focuses on the analysis review of oil and gas transport industry, and presents the importance of this activity, its future trends and socioeconomic aspects.

Keywords: Human impacts, maritime industry, energy, economic assessment.

1. Introduction

Since the centres of energy production are generally located far from the centres of consumption, international transport of oil and gas represent a vital link in the chain of energy provisioning. Hydrocarbons can be liquid or gaseous, hazardous and likely to be polluted and polluting. These characteristics give importance to their international transport characteristics, mainly done by sea, and should be transported in special containers, named tankers, or through pipelines. The Mediterranean and Black Seas contain important trade routes (22% of world´s oil trade happens in the Mediterranean Sea) with increasing relevance due to their strategic location, connecting European and non-European Countries as well as north-south and east-west regions.

The European Union's hydrocarbon energy supply relies heavily on imports. While the European Commission has recommended diversifying and increasing domestic resources, notably with renewable resources which should grow up to 20-25% by traded volume in 2025, dependence on hydrocarbon imports will remain not only important, but will increase in the years to come (Nies, 2011). It is in this context that the scenario of oil and gas transport ought to increase too with ever-increasing the potential risks of impacts to the seas and, in particular, to enclosed seas (Abdulla & Linden, 2008). Acknowledging the importance of determining the impacts of existing pressures onto marine and coastal ecosystems, a 1st regional integrated assessment of the main economic uses impacting the marine and costal ecosystems of the Mediterranean and Black Seas was performed at the Perseus project. This poster focuses on reviewing current oil and gas transport industry, and presents the importance of this activity, its future trends and socioeconomic aspects. Oil and gas transport data was obtained mostly from the Mediterranean, and although is less available from the Black Sea, both regions are analyzed with the aim of understanding the state-of-art of existing trade of Oil and Gas Transport.

3. Results

About 336 millions of tons of oil are transported across the Mediterranean Sea, mainly by ship-tankers and, marginally, by pipelines. The result of this traffic, together with being an enclosed

sea, makes it highly vulnerable to potential impacts and risks of pollution, which could led to ecological disasters.
Trade volume of gas transported through the Mediterranean Sea was 105 billion m^3 in 2010 (6 pipelines in operation), while the turnover in 2012 was of approximately €1.5 billion (minus €200 million from transit charges; BP, 2013, Pugh, 2008).

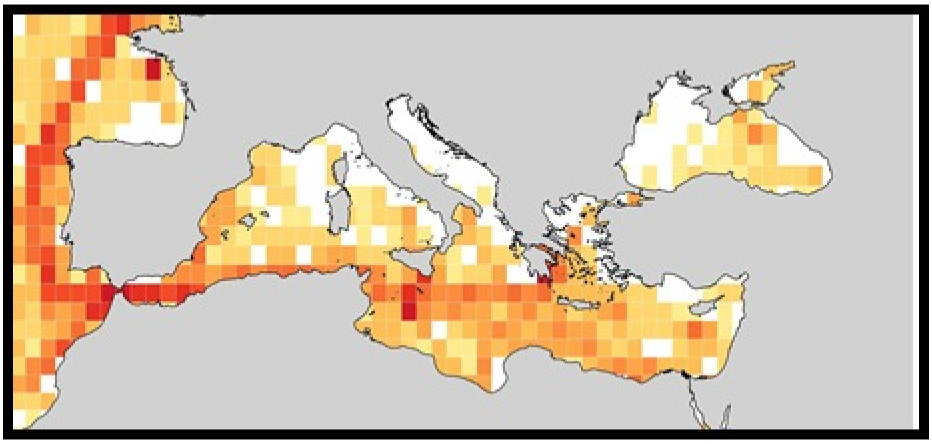

Fig. 1 *Tanker density in the Mediterranean Sea, based on satellite-AIS data (Nov 2009 – Jan 2010; Modified from PASTA MARE project).*

4. Conclusions/Discussion

The growing demand for energy will continue to increase by 2025. The trans-national nature of the Mediterranean and Black Seas presents challenging opportunities for the implementation of marine spatial plans, while considering both socio-economic aspects and environmental impacts. Progress towards sustainable development of oil and gas industry will require long-term strategies (i.e. "motorways of the seas") based on international cooperation and with the involvement of multiple stakeholders.

5. Acknowledgements

This work is part of the on-going research project entitled "Policy-oriented marine Environmental Research for the Southern European Seas" (PERSEUS) Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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AMP Toobox´s resources to design and implement adaptive policies through stakeholders engagement: Application to the case of the Marine tourism in the Mediterranean Sea

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Abstract

To achieve sustainable marine governance, stakeholders should reach a consensus about the current situation and future goals. For this purpose, decision support tools need to be developed. Accordingly, to assist policy-makers developing and implementing participatory and adaptive policies, the Adaptive Marine Policy (AMP) Toolbox has been developed. In this presentation, the structure of this innovative toolbox and some resources provided within it are shown, using the Coastal and Maritime tourism in the Mediterranean Sea as a direct issue or example. This example shows the utility of the resources to design an implementation of adaptive policies.
Keywords: Participatory tools, decision support tool.

1. Introduction

When conservation strategies for marine ecosystems follow a top-down approach that excludes local practices or interests, conflict can emerge. To achieve sustainable governance, stakeholders should reach a consensus about the current situation and future goals in a platform that allows social and technical learning (Williams and Brown 2014). In this scenario, platforms or decision support tools need to be developed to enable good governance of the marine ecosystems and ensure their sustainable exploitation whilst ensuring their preservation. Accordingly, to assist policy-makers developing and implementing participatory and adaptive management, a new Adaptive Marine Policy Toolbox (AMP-Toolbox) has been developed (http://www.perseus-net.eu/en/about_the_apf_toolbox/index.html). The AMP Toolbox consists of three major parts: (i) a guide through a five-step policy cycle; (ii) resources to accomplish the above mentioned steps; and, (iii) examples particularly relevant to the Mediterranean and Black Sea. The main objective of this presentation is to offer the structure of this innovative toolbox and some resources provided within it, using the Coastal and Maritime tourism in the Mediterranean Sea as a direct issue or example.

2. Methods

To guide the policymakers in the design and implementation of adaptive policies the toolbox has been structured in four main levels. The 1st level consists of an adaptive policy-cycle including 5 steps (i.e. set the scene; assemble a basic policy; make the policy robust; implement the policy; and, evaluate and adjust the policies). The steps (2nd level), include some basic information (e.g. objective, requirements and outputs) of the step in question, as well as the key activities necessary to accomplish each step. Activities (3rd level), include an introduction, key questions, key actions and links to the resources necessary to develop the activity in question. Resources (4th level), consist of different type of elements relevant for the Mediterranean and Black Sea. They include the knowledge base with 7 databases; the regional models and assessments; further readings; and, different tools and methods.

3. Results and Discussion

To provide details in the utility of the toolbox, in this presentation, the different resources available within the toolbox are illustrated to develop participatory and adaptive policies through stakeholders' engagement. To illustrate these resources the issue of Coastal and Maritime tourism in the Mediterranean Sea was used as an example. Accordingly, within each step a couple of resources are applied to the above mentioned issue, making always emphasis on the importance of taking multi-stakeholders into consideration. In fact, for an effective management it is necessary to engage public consultation and active partnerships from the beginning of the process. Consequently, in the 1st step (set the scene), as well as in the rest of the steps, several participatory tools such as the "Stakeholders analysis" are proposed. Additional and useful resources include the "DPSWR framework", the "Measures inventory", the "Scenarios developed within PERSEUS", the "Multi-Cases Tool (Multi-criteria analysis)" and useful "Further reading" to design and implement monitoring plans as well as evaluate and adjust policy options.

4. Conclusions

It is difficult for policy-makers to identify particular tools appropriate to design and implement adaptive policies. The example has shown that the toolbox provides useful resources for supporting policy-makers for this purpose. The update and management of these resources will impose an important challenge. Though, they suppose a practical and useful starting point to support the application and compilation of the different steps and key activities.

5. Acknowledgements

This work is part of the on-going research project named PERSEUS (Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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Adaptive Marine Policy (AMP) Toolbox: Supporting policy-makers developing adaptive policies to cope with Marine litter in the Mediterranean and Black Sea

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Abstract
Adaptive management is frequently the goal of many environmental problems but evidence on its success is still limited in many cases, such as the problem of marine litter. In fact, poor practices of solid waste management, the lack of infrastructure and a lack of awareness of the public about the consequences of their actions aggravate substantially the situation of marine litter in our oceans. In this context, it is necessary to provide a practical framework for implementing adaptive policy action to this problem. With this goals in mind, the Adaptive Marine Policy (AMP) Toolbox has been developed to operationalize the design and implementation of adaptive policies. To show its utility, the guidelines and resources provided within the toolbox have been applied to the marine litter issue in the Mediterranean and Black Seas as an example.
Keywords: Ecosystem-based approach, Southern European Seas, Adaptive management, Policy-making, Decision-support system.

1. Introduction

Several regulations at the European Union (EU) level are now requiring the application of the Ecosystem Based Approach (EBA) to manage human activities impacting marine ecosystems. On a European policy level, in 2008 the EU adopted the Marine Strategy Framework Directive to develop marine strategies and execute the necessary measures to achieve Good Environmental Status (GES) by 2020. Marine strategies should be adaptive to deal with the complex and dynamic nature of ecosystems and the absence of a complete understanding of their functioning. However, there has been only limited progress in promoting adaptive management (Farmer et al. 2012) in this context. For this reason, it is necessary to provide a practical framework for adaptive policy action. Accordingly, to operationalize the design and implementation of adaptive policies, the Adaptive Marine Policy toolbox (hereafter, AMP toolbox) has been developed. To show its utility, the guidelines provided within the toolbox are described and the different resources available illustrated, using the problem of marine litter in the Mediterranean and Black Sea as an example of operationalizing the Toolbox.

2. Structure of the AMP-Toolbox

To guide the policymakers in the design and implementation of adaptive policies, the toolbox is structured in four main levels. 1) the first level consists of an adaptive **policy-cycle** including 5 steps (i.e. set the scene; assemble a basic policy; make the policy robust; implement the policy; and, evaluate and adjust the policies). 2) The second level shows the **steps**, and includes some basic information (e.g. objective, requirements and outputs) and the key activities necessary to accomplish each step. 3) The third level has the **activities**, including key questions, key actions and links to the resources necessary to develop the activity in question. 4) The fourth level is resources, and consists on different types of elements relevant for the Mediterranean and Black Sea, including 7 databases regional models and assessments, among others.

3. Insights into the AMP Toolbox using Marine Litter as an example

To illustrate the applicability and utility of the toolbox, we go through the different steps of the AMP for the Marine litter in the Mediterranean and Black Sea. On each of the 4 levels, a couple of potential resources for marine litter management are selected, making always emphasis on the importance of taking multi-stakeholders engagement, scenario planning methods and scientific knowledge into consideration. For this, several participatory tools for implementing stakeholders' analysis are proposed. Additional resources for marine litter management include the "DPSWR framework", a "Measures inventory", the "Scenarios developed in PERSEUS", the "Multi-Cases Tool (Multi-criteria analysis)" and other sources to be able to design and implement monitoring plans as well as evaluate and adjust policy options for addressing the environmental problem.

4. Conclusions

The example of the marine litter shows how the toolbox is a useful and operational framework to build a science-policy interface according to EBA and thus improve marine governance. Although, some resources could be somewhat incomplete, and their updating and management will suppose an important challenge, they suppose a practical starting point to support the application and compilation of the different steps and key activities.

5. Acknowledgements

This work is part of the on-going research project named PERSEUS (Grant Agreement No. 287600) within the EU FP7 Theme "Oceans of Tomorrow".

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