MEDITERRANEANIZATION OF THE BLACK SEA ZOOPLANKTON IS CONTINUING

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Abstract. The introduction of Mediterranean pelagic copepod species into the Black Sea was reviewed with special reference to *Acartia tonsa*. About 60 zooplankton species and 40 phytoplankton species which are not typical for the Black Sea were discovered to have been transported from the Mediterranean Sea. Most copepod species were found only in the Bosphorus area of the Black Sea. A few species were observed in other regions as far as Crimea and Caucasus, but they were seldom. Some species can now be included in the list of the constant inhabitants of the Black Sea as had happened with their predecessors. In the present study, five copepod species, *Microcalanus pusillus, Aetideus armatus, Euchaeta marina, Metridia lucens,* and *Oncaea obscura*, were also recorded for the first time. All these species were found in the Bosphorus region. New data about occurence, distribution and abundance of the copepod *Acartia tonsa* which was recently discovered in the Black Sea are also given. The present study confirms that this species has now been naturalized in the Black Sea.

1. State of the problem

It is known that the marine flora and fauna of the Black Sea in general was formed by invaders from the Mediterranean Sea [1] after these reservoirs became permanently connected about 9000 years ago [2]. Judging by the abundance of Mediterranean species in the Black Sea, the process of invasion and acclimatisation was intensive during the period of fast increasing salinity. However, nowadays, in conditions of stable salinity, occasions of invading species spreading to the extent of becoming mass species in the Black Sea are marked [3; 4 and others].

The Bosphorus region of the Black Sea accepts invaders carried from the Marmara Sea by the Lower-Bosphorus Flow. It is from here that these species, if they survive and adapt to the new conditions will spread to other regions. All sorts of organisms, whether benthic or planktonic, carried via the Lower-Bosphorus flow are potential invaders for the Black Sea. Data about benthic animals in the Bosphorus region

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of the Black Sea not peculiar to the reservoir as a whole appeared long ago [5]. In following years the list of these species was significantly replenished [6; 7; 8 and others]. First occasions of the appearance of the Mediterranean planktonic algae in the Black Sea are described in the articles by Demir [9], Skolka [10; 11], Skolka and Bodeanu [12]. Nowadays about 40 Mediterranean phytoplankton species, originally not native to the Black Sea are known [13]. Some other Mediterranean phytoplankton species, not formerly registered were found at the Southern Crimean Coast [14; 15].

The first information about invasion of Mediterranean planktonic animals is reported by Zernov [16] who supposed that *Penilia avirostris* Dana penetrated and naturalised in the Black Sea at the beginning of this century. In 1960, six Mediterranean copepod species and siphonophora *Eudoxoides spiralis* Bigelow were found in the northwestern Black Sea [17; 18]. Undoubtedly, they came to this region from the Bosphorus where they had been transferred by the Lower-Bosphorus Flow from the Marmara Sea. In May and October 1962 [18; 19] in the Bosphorus region 11 species of the Mediterranean planktonic animals were found (2 in May and 9 in October). Later, in March 1970 in the Bosphorus region in the Mediterranean water layer, a few individuals of three Mediterranean copepod species were found [20]. In October 1972, besides some species of planktonic algae, 178 planktonic animals of 28 Mediterranean species were found at the same location [21]. Of 28 species, 19 were found there for the first time. A comparison of the appearance of Mediterranean animals in the Bosphorus region of the Black Sea with data about the intensity of water exchange through the Bosphorus [22] shows, that these organisms are mostly abundant during the periods of increasing Mediterranean water flow, in particular in March and October.

It is necessary to note that on repeated occasions, about 10 species of Mediterranean planktonic animals were recorded far from the Bosphorus, in particular near the Crimean coast including Sevastopol Bay [23; 21] . Mediterranean organisms were also found in the Danube region [24; 25]. Their appearance near the Crimean coast where they could be carried by the currents in no less than two months [23] indicates their ability for long survival and possibly for reproduction in the Black Sea (judging on the presence of juveniles and egg sacs of copepods). This forms a basis for the suggestion that in conditions of probable increasing of salinity, some Mediterranean species may be fully acclimatised and become permanent inhabitants of the Black Sea as has previously the case with now numerous members of the Black Sea fauna. Experiments have shown [26] that the present permanent fauna inhabitants of the Black Sea along with species only registered there in recent years are characterised by their high tolerance to decreasing salinity which they acquire through evolution. The recent construction of dams across important European rivers that flow into the Black Sea may have favoured the colonisation of new species from the Mediterranean Sea [27].

The marked appearance of about 60 species of zooplankton and 40 species of phyoplankton would seem to confirm conclusions by Puzanov [3] about the possible strengthening of the Mediterranization process, i.e. enrichment of the Black Sea flora and fauna by invaders from the Mediterranean Sea during a period of increasing salinity in the Black Sea.

1.1. *ACARTIA TONSA* IN THE BLACK SEA

Acartia tonsa was discovered recently (September 1990) in the Black Sea [28]. It is in fact a relatively new species for the Mediterranean being first reported there in the early 1980's [29]. After being reported in the western Mediterranean, *A. tonsa* successively spread eastward in this basin. According to Paffenhofer & Stearns [30], *A. tonsa* is adapted to high food concentrations and therefore its appearance in the Black Sea is interesting though not surprising when the gradual increase in eutrophication over the last few decades is considered.

2. Materials and Methods

Zooplankton samples were collected during three different R/V "Bilim" cruises. In September 1995 and April 1996 sampling was carried out in the Bosphorus area using a Nansen net (d = 70 cm, mesh size = 112 μm). All Mediterranean zooplankton in those samples were isolated and identified. Other samples were taken from the entire Turkish Exclusive Economic Zone (TEEZ) in September-October 1996 (Fig.1). In those samples, all adult individuals and copepodites belonging to *Acartia* genus were identified and counted. Size measurements of some copepods were also taken.

We also used the samples collected at three stations near Sevastopol (the Crimea) during February - August 1996 and February 1997. These samples were collected with a Juday net (d = 38 cm, mesh size = 140 μm). The stations were located 0.100 km, 1 km and 3 km offshore respectively.

3. Results and Discussion

The list of Mediterranean copepod species in the Black Sea is given in Table 1. We found five new copepod species for the Black Sea which are also included in this Table. These five species were *Microcalanus pusillus*, *Aetideus armatus*, *Euchaeta marina*, *Metridia lucens*, and *Oncaea obscura*, all of which were found in the Bosphorus region. In this region as well as in all stations sampled during September-October 1996, we also found *Acartia tonsa* which was previously reported only once in the Black Sea, near the Crimean coast [28]. However in that report authors did not give any information on the abundance and distribution of this species. *Acartia tonsa* is new even for the Mediterranean as it was absent in the list of Mediterranean copepods

TABLE 1. The list of Mediterranean copepods, which were found in the Black Sea.
* only copepodites, except in the western region where one adult *C. typicus* was found in 1995. N = New species.
Reference: 1- Pavlova [17; 18], Pavlova and Baldina [19]. 2- Kovalev *et al.* [21]. 3- Kovalev [20]. 4- Kovalev *et al.* [25]. 5- Porumb [24]. 6- The present study.

	Reference					
Species	1	2	3	4	5	6
Calanus tenuicornis Dana					+	
Calanus gracilis Dana		+				
Calanus minor Claus				+		
Eucalanus sp.					+	
Mecynocera clausi J.C.Thompson				+	+	
Paracalanus nanus Sars				+	+	
Paracalanus aculiatus Giebr.					+	
Clausocalanus arcuicornis (Dana)	+	+	+			
Clausocalanus paululus Farr.		+	+	+		
Calocalanus furcatus (Brady)		+				
Clausocalanus pergens Farr.		+		+		+
Clausocalanus parapergens Frost,Flem		+				
Clausocalanus mastigophorus (Claus)				+		
Calocalanus pavo Dana	+	+	+	+	+	
Calocalanus plumulosus Claus					+	
Calocalanus pavoninus Farr.	+		+			
Calocalanus plumatus Shmel.		+		+		
Calocalanus (tenuis?) Farr.			+			
Microcalanus pusillus .O.Sars						N
Ctenocalanus vanus Giesbr					+	+
Aetideus armatus Boeck						N
Euchaeta marina Prestandrea						N
Phaenna spinifera Claus					+	
Scolecithrix danae Lubb		+				
Temora stylifera Dana				+		
Metridia lucens Boeck						N
Pleuromamma abdominalis Lubb				+		
Pleuromamma gracilis Claus				+		+*
Pleuromamma sp.		+				
Centropages typicus Kroyeri				+		+*
Lucicutia flavicornis Claus			+			
Lucicutia gemina Farr.				+		
Euterpina acutifrons Claus	+	+	+	+		
Candacia aethiopica Dana		+				
Acartia tonsa Dana						+
Microsetella rosea Dana	+	+	+	+		+
Macrosetella gracilis Dana		+				
Paroithona parvula Farr.				+		
Oithona sp.		+	+			+
Oncaea obscura Farr.						N

TABLE 1. Continued.

Oncaea minuta Giesbr.	+	+	+	+		+
Oncaea dentipes Giesbr.	+	+	+	+		+
Oncaea similis Sars		+	+	+		
Oncaea media Giesbr.		+		+		
Oncaea subtilis Giesbr.		+				
Oncaea curta Sars		+		+		
Oncaea conifera Giesbr.		+				
Oncaea mediterranea Claus	+		+	+	+	
Oncaea subtilis Giesbr.				+		
Oncaea venusta Philippi				+		
Corycaeus furcifer Claus	+	+	+		+	
Corycaeus latus Dana		+		+		
Corycaeus typicus Kroger	+		+	+		
Corycaeus flaccus Giesbr.	+		+			
Corycaeus clausi F.Dahl	+		+			
Corycaeus limbatus Brady				+		
Corycaeus sp.	+		+	+		
Corycella gracilis Dana		+				
Corycella rostrata Claus				+		
Corycella sp.	+		+			

compiled for the early 1980's [31]. Its first appearance in the Mediterranean Sea was in the mid-eighties [29]. Our data, collected in the TEEZ, show that the abundance of *A. tonsa* adults exceeded 1000 ind. m^{-2} in some stations during the autumn of 1996 (Fig. 1). The *A. tonsa* abundance at two stations was even more than the abundance of the native species *A. clausi*. In those samples *A. tonsa* was represented by all development stages. Maximum abundance occurred at a station nearest to the Bosphorus area. *A. tonsa* abundance decreased in the middle region of the Black Sea, increasing again in the south-east. Similar distribution patterns of some Atlantic forms are also known in the Mediterranean Sea [32], where abundances in eastern regions are higher than in western and central areas.

We also found *A. tonsa* in the coastal waters of Crimea in 1996. Abundances of *A. clausi* and *A. tonsa* in 1996 and 1997 at two stations near Sevastopol are presented in Fig. 2. At the most inshore station (st.1 near Sevastopol) the abundance of *A. tonsa* adults increased to 512 ind m^{-3} in the surface layer (0-10 m) in July 1996. The total number of *A. tonsa* adults was higher than that of *A. clausi* at St. 1 in summer. Only at the end of winter was the abundance of *A. tonsa* less than *A. clausi* at this station. Moving to the open sea (St. 3) the abundance of *A. clausi* adults became greater than *A. tonsa* both in summer and winter (Fig. 2). In spring *A. tonsa* was absent at Station 3.

From the literature [33] it is known that *A. tonsa* is more tolerant of salinity changes, but its development is limited by low temperature. On the contrary the native species, *A. clausi* is more stenohaline and begins breeding at lower temperatures than *A. tonsa*. Due to its high salinity tolerance *A. tonsa* numbers may be expected to increase in bays especially in the summer. In such environments, this species may replace the small form of *A. clausi* of which numbers are already reduced now. The more stenohaline species *A. clausi* may maintain its abundance in the open sea. In winter, the abundance of *A. tonsa* may be limited by the low temperature and the abundance of *A. clausi* is then expected to increase in coastal regions.

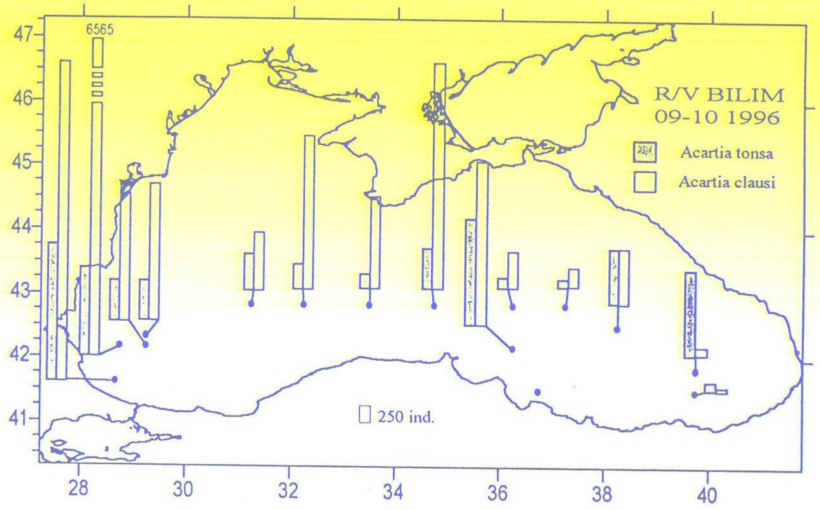

Figure 1. Abundance (ind. m^{-2}) of genus *Acartia* during September 1996 in the Black Sea.

Some investigations have shown that *A.tonsa* inhabits the areas in the Mediterranean Sea named the Sub-Atlantic which include the French coasts and the North Adriatic lagoons [34]. In October 1996, *A.tonsa* was also abundant in the Sea of Marmara (unpublished data of A. Kovalev and Yu. Zagorodnyaya), from where it may enter the Black Sea via the Lower-Bosphorus Flow.

Body length measurements of adult *A. tonsa* showed that individuals from the Black Sea were smaller than those from the Marmara Sea. In the Black Sea the average lenght of *A.tonsa* females and males was 0.879±0.032 mm and 0.812±0.021 mm, respectively. While in the Sea of Marmara, respective values were 1.011±0.027 mm and 0.924±0.032 mm. This finding together with the distribution pattern obviously indicates the existence of the *A. tonsa* population indigenous to the Black Sea to be different from the Sea of Marmara population. It is known that some species of copepods, following their invasion and acclimatisation have reduced their size in the Black Sea [35]. The reduction in size is also observed for some warmwater forms and eurythermal copepoda. It is well known from Jeffries [33] that *A. tonsa* inhabiting New England and Middle Atlantic estuaries is a summer-fall form. *A. tonsa* being a warmwater form should reduce its size in the Black sea. As it is known, temperature and salinity are among the major factors affecting the size of animals. The reduction in the size of *A. tonsa* in the Black Sea confirms what is already known that environmental factors determine changes in animal sizes.

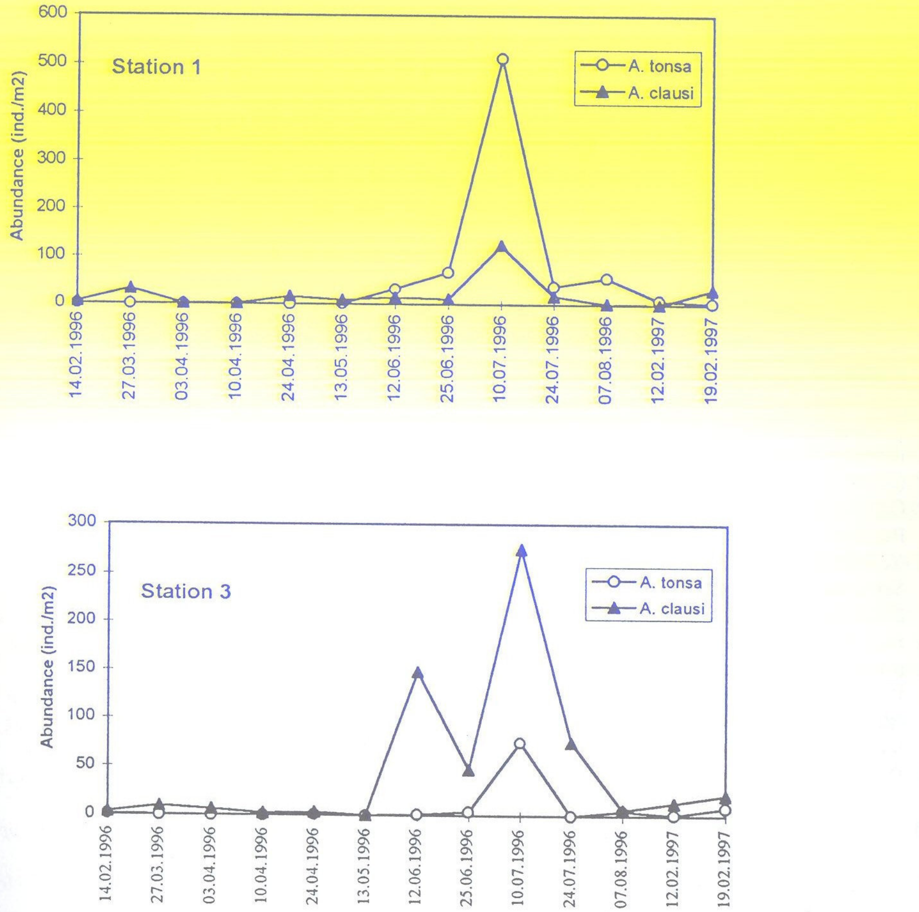

Figure 2. Temporal changes in the abundance of *Acartia tonsa* and *Acartia clausi* at two stations of Crimea.

4. Conclusions

The data submitted in the present article testify the intensive transport of planktonic organisms from the Mediterranean Sea to the Bosphorus region of the Black Sea. Natural and anthropogenic changes in the environment may favour invasion processes. Thus enrichment of the Black Sea biota will not only be due to species transportation from the Mediterranean Sea but also from oceanic invaders as it happened with *Acartia tonsa*.

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References

1. Zenkevich, L.A. (1963). Biology of seas of the USSR. *M. Acad. nauk. USSR*:739 (In Russian).
2. Deuser, W.G. (1974). Evolution of anoxic conditions in Black Sea during Holocene, in E.T. Degens and D.A. Ross (eds.), *The Black Sea - Geology, Chemistry and Biology*, Publ. by the American Assoc. of Petroleum Geologists, Tulsa, Oklahoma, U.S.A., 111-136.
3. Puzanov, I.I. (1967). Mediterranization of fauna of the Black Sea and prospects of its strengthening. *Zoologich. Zhurnal* 46,9 :1287 (In Russian).
4. K'neva, B. and Marinov, T. (1984). New species mollusca in the Black Sea *Cunearca cornea* (Reeve). *Priroda, NRB*.5,33:63-64 (In Bulgarian).
5. Ostroumov, A.A. (1893). Trip to the Bosphorus. *Zapiski Imperat. Acad. nauk.* 72,8 (annex):1-55 (In Russian).
6. Yakubova, L.I. (1948). Features of biology of the Bosphorus region of the Black Sea. *Trudi Sevastop.biol stanchii*.6:274-285 (In Russian).
7. Bacesco, M. and Marginneanu, C. (1959). Elements mediterraneens nouveaux por la faune de la mer Noir trouves dans les eaux de Roumelie (Nord-ouest-Bosphore). Donnees nouvelles pour le probleme du peuplement actuel de la mer Noir. *Arch. oceanogr. elimno l. 2suppl.* :63-74.
8. Kiseleva, M.I. (1969). Composition and distribution of benthos in the Bosphorus region of the Black Sea, in *Water exchange through the Bosphorus and its influence on hydrology and biology of the Black Sea*. Kiev, Naukova dumka :233-253 (In Russian).
9. Demir, M. (1954). Turkiyeye sahil veren iki buyuk icdenizin bazi fiziko-simik hususiyetleri ve bunlarin faunaya tesirleri.-*Hidrobiologi Mecmuasi, Cilt II, Sayi 3, Seri A*, Istanbul .
10. Skolka, V.H. (1960). Especes phytoplanctoniques des eaux roumaines de la Mer Noire. *Rapp. et P.V.Comm. int.Explor. sci. Mer. Medit., v.15(2)*:249-268.
11. Skolka, V.H. (1961). Donnees sur le phytoplancton des parages psebosphoriques de la Mer Noire, *Rapp. et P.V.Comm.int.Explor.sci. Mer.Medit., v.16(2)*:129-132
12. Skolka, V.H. and Bodeanu, N. (1963). Researches of phytoplankton of the coastal regions of the Black Sea. *Rev. biol. Acad. RPR. 7,1* :89-104
13. Georgieva, L.V. (1993). Species composition and dynamics of phytoplankton, in *Plankton of the Black Sea*. Kiev. Naukova dumka . :31-54 (In Russian).
14. Kuzmenko, L.V. (1966). Two species of Dinoflagellata, new for the Black Sea. *Novosti systematiki nisshix rasteniy Acad. nauk. Botanich. institution. Moscow-Leningrad* :51-54 (In Russian).
15. Senichkina, L.G. (1973). Phytoplankton of clean and polluted by industrial and agricultural flows waters in the Yalta region. *Biologya morya 28* :135-150 (In Russian).
16. Zernov, S.A. (1908). Penilia schmacceri Rich in the Black Sea and in the Karkinit Gulf. *Ejegodnic zoological museum Imperat. Acad. nauk. 13,4*:500-502 (In Russian).
17. Pavlova, E.V. (1964). About the founding Mediterranean species in the Black Sea zooplankton. *Zoological journal. 43,11.*:1710-1713.
18. Pavlova, E.V. (1965). Penetration of the Mediterranean planktonic organisms into the Black Sea, in *Basic features of geological structure, hydrological conditions and biology of the Mediterranean Sea*. Moscow. Nauka :171-174(In Russian).

19. Pavlova, E.V. and Baldina, E.P. (1969). Influence of water exchange through the Bosphorus on distribution and composition of zooplankton of the Bosphorus region, in *Water exchange through the Bosphorus and its influence on hydrology and biology of the Black Sea*. Kiev. Naukova dumka :208-232 (In Russian).
20. Kovalev, A.V. (1971). To the question about coming plankton animal into Black Sea from Mediterranean, in *Oceanographic investigations in Tunis Channel*, 120-122 (in Russian).
21. Kovalev, A.V., Georgieva, L.V., and Baldina, E.P. (1976). Influence of water mass exchange from Bosphorus on the content and distribution of the plankton in the nearest seas, in *Investigation of Water Mass Exchange from Tunis Channel and Bosphorus*, 181-189 (in Russian).
22. Bogdanova, A.K. (1976). Entering and distribution of the Mediterranean waters in the Bosphorus region of the Black Sea, in *Investigations of water exchange through the Tunisian Gulf and the Bosphorus*. Kiev. Naukova dumka :68-73 (In Russian).
23. Bogdanova, A.K. and Shmeleva, A.A. (1967). Hydrological conditions of penetrating of the Mediterranean species into the Black Sea, in *Water dynamics and questions on hydrochemistry of the Black Sea*. Kiev. Naukova dumka :156-166 (In Russian).
24. Porumb, F. (1980). Presence de guelgues especes mediterraneenes dans le zooplancton de la Mer Noire. *Rev.roum biol.ser.biol. animal. Acad. R.S.R. 25,2,* :167-170.
25. Kovalev, A.V., Shmeleva, A.A., and Petran, A. (1987). Zooplankton of the west part of the sea from Bosphorus to Danube in the May 1982, in *Dynamic of the Water mass and Productivity of the plankton of the Black Sea*, 356-367 (in Russian).
26. Kovalev, A.V. (1966). Surviving of some pelagical copepods of the Black and Mediterranean Seas in waters of different salinity . *Hydrobiological Journal. 2,1.*:43-48 (In Russian).
27. Moraitou-Apostolopoulou, M. (1985). The zooplankton communities of the Eastern Mediterranean (Levantine Basin, Aegean). NATO Confer. Ser., Ecol.8: 303-309.
28. Belmonte, G., Mazzocchi, M.G., Prusova, I.Yu., and Shadrin, N.V. (1994). *Acartia tonsa* a species new for the Black Sea fauna. *Hydrobiologia 292/293*: 9-15.
29. Gaudy, R. and Vinas, M.D. (1985). Premiere signalization en Mediterranee du copepode pelagique *Acartia tonsa*. *Rapp. Comm. int. Mer Medit. 29*: 227-229.
30. Paffenhofer, G.A. and Stearns, D.E. (1988). Why is *Acartia tonsa* (Copepoda:Calanoida) restricted to nearshore environments? *Marine Ecology Prog. Ser. 42*:33-38.
31. Kovalev, A.V. and Shmeleva, A.A. (1982). Fauna of Copepoda in the Mediterranean Sea. *Ecologiaya Moria 8*:82-87 (in Russian).
32. Kovalev, A.V. (1991). The structure of zooplankton communities of the Atlantic Ocean and Mediterranean basin. *Kiev, Naukova dumka*, 144 pp (in Russian).
33. Jeffries, H.P. (1962). Succession of two *Acartia* species in estuaries . *Limnology and Oceanography 7, 3.*:354-364.
34. Sacchi, C.F., Occhipinti-Ambrogi, A., and Sconfietti, R. (1992). Les lagunes Nord-Adriatijues: un environment conservateru ouvert aux noveautes. *Bull. Soc. Zool. France 114*:47-60.
35. Kovalev, A.V. (1968). Sur la variabilite des demensions de quelques Copepodes planctoniques dans les mers du bassin Mediterraneen. *Rapp. Comm. int. Mer medit. 19,3*:441-443.