Zooplankton of the Black Sea and the Eastern Mediterranean: Similarities and dissimilarities

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Zooplankton of the Black Sea and the Eastern Mediterranean: Similarities and dissimilarities

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Abstract

A synthesis of data on abundance and biomass of zooplankton in the Eastern Mediterranean (EMED) and the Black Sea shows major differences in the composition and structure of pelagic communities in the two basins. Few Mediterranean planktonic animals have invaded in the Black Sea. The great bulk of Black Sea species is represented by coastal inhabitants that spread throughout the whole basin. This process has been called “neritization” of the Black Sea fauna. Peculiarities in zooplankton assemblages of the Black Sea have been further strengthened over the last few decades due to increasing eutrophication and the massive invasion of the ctenophore Mnemiopsis leidyi. The relative contribution of copepods, cladocerans, chaetognaths, and appendicularians to total zooplankton biomass has notably decreased, whereas gelatinous groups (mainly represented by Mnemiopsis and Aurelia aurita) contributed up to 99% of total wet weight in 1995 in the Black Sea.

The basic features of planktonic fauna in the Black Sea are mainly due do the geo-morphological characters of the basin and the limited exchanges with the EMED, that are confined to the surface-sub-surface layers in the Dardanelles and Bosphorus Straits. However, the dramatic changes that have recently occurred in the structure of zooplankton assemblages seem to have been caused by heavy anthropogenic impact on the pelagic system.

Keywords: Zooplankton, Eastern Mediterranean, Black Sea, Abundance, Biomass.
**Introduction**

The pelagic environments of the Eastern Mediterranean (EMED) and the Black Sea share some basic common features due to their connection through the Dardanelles and Bosphorus Straits, dating back 5000-6000 years. Some similarity is evident in the composition of flora and fauna (Zenkevich, 1963), and the zooplanktonic communities in both regions consist mainly of species of Atlantic origin. However, geographical and geo-morphological characteristics are responsible for noticeable differences in hydrology, environmental parameters such as temperature and salinity (Table 1) and in biological production. The straits are narrow and shallow and allow limited water exchange which occurs only in the surface layer (Ovchinnikov et al., 1976), preventing the entrance of deep-water species from the EMED to the Black Sea. The relatively larger volume of freshwater flowing from rivers into the Black Sea is responsible for a higher organic matter production in comparison with the EMED (Kovalev, 1991). This nutrient enrichment has further increased in recent years because of heavy anthropogenic impact (Altman et al., 1990; Zaitsev & Alexandrov, 1997). Moreover, anoxic conditions below 200 m in the Black Sea, with high levels of hydrogen sulphide, result in an azoic environment below the epipelagic zone (Sorokin, 1982). The combination of these peculiar conditions have finally established a characteristic zooplankton community in the Black Sea.

We provide here data on the major differences between the mesozooplankton assemblages of the EMED and the Black Sea, both in terms of species composition, abundance and biomass. We also discuss some considerable changes which have recently occurred in the pelagic system of the Black Sea.

**Materials and Methods**

The present contribution is mainly based on data collected during cruises of the Institute of Biology of the Southern Seas (IBSS), in the EMED and Black Sea from 1957 to 1982 (for the sampling data see, Kovalev et al., 1996a for the EMED and Petipa et al., 1963, Sazhina, 1964, Fedorina, 1978, Kovalev et al., 1996 for the Black Sea) and on data from the literature. In order to explain the important changes occurring in the last two decades, recent data obtained during the 1990's were also utilized (Kovalev et al., 1996; 1999b; Kovalev & Piontkovski, 1998).

Studies carried out by other institutes had in general employed different methods for sample collection and processing and are hardly comparable. For this reason, the present study has mainly focused on data from the IBSS since data was obtained from

| Region            | Summer | Winter |
|-------------------|--------|--------|
|                   | T°C    | S ‰   | T°C    | S ‰   |
| North Adriatic    | 22-23  | 33-37 | 8-12   | 36-38.5 | Ovchinnikov et al., 1976 |
| South Adriatic    | 24-25  | 38-38.25 | 13.5 | 38.5 | Ovchinnikov et al., 1976 |
| North Aegean      | 24-27  | 33-37 | 12-14 | 37-38.5 | Ovchinnikov et al., 1976 |
| South Aegean      | 24     | 38-39 | 16-17 | 38.5-39 | Ovchinnikov et al., 1976 |
| Ionian Sea        | 25     | 38.25-38.75 | 14-15 | 38.25-38.75 | Ovchinnikov et al., 1976 |
| Levantine Sea     | 25-27  | 39-39.25 | 16-17 | 38.5-39 | Ovchinnikov et al., 1976 |
| Black Sea         | 21-27  | 18.24 | 0-9    | 17.44 | Zenkevich, 1963 |

Table 1

Surface temperature and salinity values in the EMED regions and Black Sea.
the two basins by utilizing similar methods. Samples were collected by vertical hauls from standard depth layers (0-10, 10-25, 25-50, 50-100, 100-150/200 m) or through integrated water columns (0-100, 0-200 m or 0-bottom) using Juday nets with a mesh size of 125 µm. Data of abundance (ind. m⁻³) and biomass (as g m⁻³ wet weight) are provided for zooplankton collected in open water regions.

It is important for comparison purposes, that the material was collected during the same period in both seas (e.g. 1957-1982), when the anthropogenic influence on pelagic ecosystems was still relatively weak. Cruises took place in different seasons of the year, therefore the results obtained demonstrate both average annual and seasonal values of biomass and abundance in different regions of the EMED (Kovalev et al., 1999a) and of the Black Sea (Fedorina, 1978; Petișta et al., 1963; Sazhina, 1964).

Results and Discussion

About 150 zooplanktonic species are reported for the Black Sea, including numerous brackish-water and freshwater organisms, which are restricted to the northwestern and other coastal areas (Koval, 1984). This number differs by one order of magnitude from that reported for the whole Mediterranean (Kovalev, 1991). Only about 50% of the Black Sea species occur in the Mediterranean. Therefore, the taxonomic composition of zooplankton in the EMED and Black Sea shows some remarkable differences. All taxonomic groups of planktonic animals are presented in the EMED, but only a few of them have penetrated into and acclimatized in the Black Sea. This feature seems to be mainly due to differences in salinity between the two basins. Typical stenohaline marine organisms such as radiolarians, siphonophores, pteropods, and salps, which are common in the Mediterranean, do not occur in the Black Sea. Abundantly occurring groups such as copepods, chaetognaths, medusae are present in much reduced numbers in the EMED (Table 2).

Zooplankton in the Black Sea is characterized by the absence of mesopelagic and deep sea species because the water exchanges with the EMED are confined to the surface and sub-surface layers. Due to the extended continental shelf, the neighbouring North Aegean Sea is characterized by mixed neritic-pelagic assemblages but only strictly neritic species penetrate into the Black Sea. For instance, five out of six EMED cladoceran species (Eudne nordmanni, E. spinifera, E. tergestina, Podon polyphemoides, Penilia avirostris), and three out of fifteen species of Pontellidae copepods (Pontella mediterranea, Anomalocera patersoni, Labidocera brunescens) are reported from the Black Sea (Koval, 1984; Lakkis et al., 1999).

The intruding zooplankters are euryhaline and eurythermic animals, able to survive and reproduce even in a marine envi-

| Group of Zooplankton | EMED | Black Sea | Reference |
|----------------------|------|-----------|-----------|
| Copepoda             | 313  | 12        | Kovalev, Shmeleva, 1982; Koval, 1984 |
| Cladocera            | 6    | 5         | Lakkis et al., 1999, Koval, 1984 |
| Siphonophora         | 25   | 0         | Lakkis et al., 1999, Koval, 1984 |
| Appendicularia       | 15   | 1         | Lakkis et al., 1999, Koval, 1984 |
| Chaetognatha         | 10   | 1         | Lakkis et al., 1999, Koval, 1984 |
| Hydrozoa             | 70   | 7         | Lakkis et al., 1999, Koval, 1984 |
An environment characterized by very low salinity values (18 ‰) and high seasonal variations in water temperature (0-27°C). Most of the species invading the Black Sea occur only in coastal areas of the EMED, whereas in the Black Sea they are distributed throughout the entire basin. The notable success of their populations in open waters is probably supported by the high levels of eutrophication over the whole Black Sea basin. This phenomenon of intrusion and mass development of these species has been called “neritization” of the Black Sea fauna (Kovalev, 1991). This process is similar to that reported for the Adriatic Sea by Hure et al. (1980). Factors that play major roles in these dynamics are probably: 1) the small size of these seas, with high surface/volume ratio, 2) nutrient enrichment affecting the entire basins through river inflow, 3) intensive water-exchange between coastal and deep-water regions providing diffusion of neritic species into the whole of the water column.

The values of total mesozooplankton abundance differ by one order of magnitude between the EMED and the Black Sea. In epipelagic waters (0 - 200 m) of the EMED, the values range between 100 - 1000 ind.m\(^{-3}\) (Greze, 1989). Only in more eutrophic neritic regions (such as the North and Central Adriatic and the North Aegean Sea), does total abundance show higher values (Kovaev et al., 1999a). In the open Black Sea, zooplankton assemblages are generally more abundant (mean value for the year about 10,000 ind. m\(^{-3}\)). The values may reach up to 40,000 and even 70,000 ind.m\(^{-3}\) in spring and summer, respectively (Table 3), in the north-western area which is under the influence of large river inflow.

In terms of group composition, mesozooplankton communities differ between the two basins. According to historical data (1957-1982), copepods accounted for 70 to 96% of total zooplankton numbers in the EMED, whereas in the Black Sea their relative abundances ranged from 60 to 80%. Among other major groups, cladocerans, appendicularians, and gelatinous organisms occurred with higher relative abundance in the Black Sea (Table 4).

Remarkable differences between the EMED and the Black Sea have also been recorded for total zooplankton biomass. Reports from Soviet surveys held during 1957-1982 throughout the basins (Delalo, 1966; Greze, 1989) show that wet weight values in the EMED ranged from 18.0 mg m\(^{-3}\) to 56.0 mg m\(^{-3}\) in the warm period of the year for the layer 0-200 m. Winter - spring values were within this range. In the Black Sea, the same parameter was in the order of 500 - 1000 mg m\(^{-3}\) in summer (Table 5). The contribution of different groups to total zooplankton biomass also differed between the EMED and Black Sea. In the 0-200 m layer, copepods constituted 42-75% of the

| Region                      | Season                  | Abundance (ind. m\(^{-3}\)) | Reference            |
|-----------------------------|-------------------------|-----------------------------|----------------------|
| South and Middle Adriatic   | summer                  | 1724                        | Greze et al., 1982   |
| Ionian Sea                  | summer                  | 1041                        | Greze et al., 1982   |
| Aegean Sea                  | summer                  | 1032                        | Greze et al., 1982   |
| Levantine Sea               | summer-autumn           | 1397                        | Delalo, 1966         |
| Black Sea, different regions| all seasons             | 10000                      | Petipa et al., 1963  |
| Black Sea, north western part| spring                  | 37320                      | Sazhina, 1964        |
| Black Sea, north western part| summer                  | 70960                      | Sazhina, 1964        |
Table 4
Percentage of total zooplankton abundances (ind. m$^{-3}$).

| Region            | Season Year     | Copepods | Chaetognaths | Gelatinous Appendicularians | Cladocerans | Ostracods | Reference       |
|-------------------|-----------------|----------|--------------|-----------------------------|-------------|-----------|-----------------|
| Sicily Channel    | autumn 1991     | 81.83    | 2.43         | 0.79                        | 5.49        | 0.42      | 5.43 MAZZOCCHI et al., 1997* |
| Ionian Sea        | autumn 1991     | 79.11    | 8.09         | 1.33                        | 2.04        | 0.53      | 6.55 MAZZOCCHI et al., 1997* |
| Cretan Sea        | autumn 1991     | 88.57    | 3.22         | 0.23                        | 1.9         | 0.09      | 4.27 MAZZOCCHI et al., 1997* |
| Cretan Passage    | autumn 1991     | 77.21    | 5.86         | 1.19                        | 0.78        | 0.13      | 9.61 MAZZOCCHI et al., 1997* |
| Rhodos area       | autumn 1991     | 74.68    | 3.53         | 0.65                        | 9.44        | 0.46      | 6.61 MAZZOCCHI et al., 1997* |
| Levantine Sea     | autumn 1991     | 82.91    | 1.52         | 2.79                        | 4.17        | 0.02      | 5.57 MAZZOCCHI et al., 1997* |
| Adriatic Sea      | summer 1960     | 96       | 0.59         | 0.24                        | 1.2         | 0.21      | 0.66 GREZE et al., 1982** |
| Ionian Sea        | summer 1959     | 94.6     | 0.54         | 0.34                        | 1.2         | 0.37      | 0.85 GREZE et al., 1982** |
| Levantine Sea     | summer 1959     | 87.4     | 0.28         | 0.38                        | 1.26        | 0.14      | 0.6 GREZE et al., 1982** |
| Gulf of Sirte     | summer 1959     | 88.9     | 0.5          | 0.28                        | 1.15        | 0.1       | 0.5 GREZE et al., 1982** |
| Aegean Sea        | summer 1958, 1960 | 86   | 0.68         | 0.38                        | 1.8         | 0.55      | 0.39 GREZE et al., 1982** |
| Black Sea         | May 1957        | 71       | 0.08         | 19                          | 4.5         |           | SAZHINA, 1964** |
| Black Sea         | August 1957     | 57.8     | 1.5          | 10                          | 3.6         | 20        | SAZHINA 1964**  |
| Black Sea         | spring-autumn   | 61.3     | 0.3          | 25.3                        | 2.3         |           | FEDORINA, 1978*** |

* - Layer 0-300 m, Wp3 Net, Mesh Size 200 µm
** - Layer 0-200 m, Juday Net, Mesh Size 125 µm
*** - Layer 0-100 m, Juday Net, Mesh Size 200 µm
EMED fauna, followed by chaetognaths (9-13%) and appendicularians (3.8-15.6%). The contribution of other groups was not significant (GREZE, 1989). The three mentioned groups also dominated in the Black Sea, but with much lower percentages, because a considerable fraction of the biomass was represented by *Noctiluca scintillans* (up to 62% in 1960-1969) and gelatinous organisms such as *Pleurobrachia rhodopis* (35% in 1959-1974) (FEDORINA, 1978; MASHTAKOVA, 1985).

In recent decades, a remarkable increase in the anthropogenic impact on the ecosystem of the Black Sea has noticeably affected the species composition of zooplankton assemblages (KIDEYS et al., 2000). In the 1970 - 80s, the abundance of common species especially those inhabiting the surface layer, greatly decreased (POLISCHUK et al., 1984; ZAITSEV, 1992). This change was further pronounced after the invasion of the ctenophore *Mnemiopsis leidyi*. The transport of this species in ballast waters from the northwestern Atlantic caused major changes in the structure and dynamics of pelagic communities in the Black Sea after 1988. The previously dominant cyclopoid *Oithona nana* and the calanoid *Labidocera brunescens* no longer occur in zooplankton samples (KOVALEV et al., 1993; ZAGORODYAYA & SKRYABIN, 1995). In the north-western Black Sea, the abundance of hyponeustonic copepods (i.e. *Pontellidae*) decreased by 35 fold between 1960 and 1980. In the same region, *Paracalanus parvus*, *Centropages ponticus*, *Pseudocalanus elongatus*, *Calanus euxinus* (helgolandicus), *Sagitta setosa*, *Penilia avirostris* and *Evadne spinifera* decreased by some 4 to 50 fold for the same period (POLISCHUK et al., 1984).

All these dramatic changes recently observed in the pelagic system of the Black Sea seem to be due to the toxic impact of pollution and heavy predation by *Mnemiopsis leidyi* on zooplanktonic animals (POLISCHUK et al., 1984; ZAITSEV, 1992; KIDEYS, 1994; KOVALEV & GUBANOVA, 1995; KOVALEV et al., 1998; KIDEYS et al. 1999).

Significant long-term changes in zooplankton assemblages occurred in the Black Sea between the period 1950-70 and 1995 (Table 5). The number of some groups and

### Table 5

| Organisms                  | March-August 1959-1974, (0-100 m) (FEDORINA, 1978) | January, April, August 1995, (0-150m) (KOVALEV et al., 1996) |
|----------------------------|---------------------------------------------------|-------------------------------------------------------------|
|                            | Abundance (ind. m<sup>3</sup>) | %       | Abundance (ind. m<sup>3</sup>) | %       |
| Copepoda                   | 5125                                      | 65.1    | 983                                | 52.7    |
| Cladocera                  | -                                         | -       | 100                                | 5.5     |
| Oikopleura dioica          | 220                                       | 2.7     | 3                                  | 0.15    |
| Bivalve larvae             | 257                                       | 3.3     | 58                                 | 3.3     |
| Sagitta setosa             | 22                                        | 0.3     | 4                                  | 0.2     |
| Noctiluca scintillans      | 1905                                      | 24.1    | 715                                | 38.0    |
| Pleurobrachia rhodopsis    | 74                                        | 0.9     | 1.2                                | 0.05    |
| Mnemiopsis leidyi          | 0                                         | 0       | 2.3                                | 0.1     |
| Other                      | 236                                       | 3.6     | -                                  | -       |
| Total                      | 7639                                      | 100.0   | 1868                               | 100.0   |
species such as total copepods, *Oikopleura*, and *Pleurobrachia* decreased considerably as well as their relative contribution to total abundances. The opposite trend was observed for *Noctiluca*. Over the past few decades, gelatinous zooplankters have overwhelmed the remaining groups in terms of numerical abundance and biomass. A significant part of the planktonic biomass consisted of *Noctiluca scintillans* (up to 62% during 1960-1969) and *Pleurobrachia rhodopis* (35% during 1959-1974). *Mnemiopsis* accounted for only 0.1% of total numbers in 1995 but its contribution to zooplankton biomass was much higher because of its relatively large size. In 1995, the gelatinous component (mainly *Mnemiopsis leidyi* and *Aurelia aurita*) accounted for 99.5% of total zooplankton biomass as wet weight (*KOVALEV & PIONTKOVSKI*, 1998) (Table 6).

## Table 6
Total biomass of zooplankton (mg m\(^{-3}\)) in the EMED and Black Sea in 0-200 m layer (Juday Net, mesh size 125 μm).

| Region                    | Season, Year          | Biomass (mg m\(^{-3}\)) | Reference                  |
|---------------------------|-----------------------|--------------------------|----------------------------|
| South and Middle Adriatic | Summer, 1960,1982     | 56.0                     | *GREZE et al.*, 1982       |
| Ionian Sea                | Summer, 1959, 1960    | 33.0                     | *GREZE et al.*, 1982       |
| Aegean Sea                | Summer, 1958, 1960,168| 23.0                     | *GREZE et al.*, 1982       |
| Levantine and Sirte Seas  | Summer, Autumn, 1959,1960 | 18.0                 | *DELAO*, 1966             |
| Black Sea                 | all year 1960-1974    | 400*                    | *GREZE et al.*, 1979       |
| Black Sea                 | different seasons, 1957| 257                     | *PETIPA et al.*, 1963      |
| Black Sea                 | Summer, 1980          | 597                     | *KOVALEV & PIONTKOVSKI*, 1998|
| Black Sea                 | Summer, 1990          | 1005 (6495) **          | *KOVALEV & PIONTKOVSKI*, 1998|
| Black Sea                 | Summer, 1995          | 517 (12535) **          | *KOVALEV & PIONTKOVSKI*, 1998|

* - Layer 0-100 m, mesh size 200 μm  
** - Including *Aurelia aurita* and *Mnemiopsis leidyi*

Conclusion

The basic features in the planktonic fauna of the Black Sea greatly differ from that of the EMED. This difference in zooplankton composition has been aggravated in recent years due to sensitivity of the Black Sea ecosystem because of anthropogenic impact.

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References

*ALTMAN, E.N., BEZBORODOV, A.A. & BOGATOVA, Yu.J.*, 1990. Applied ecology of sea regions: The Black Sea (eds. Keondjian V.P., Kudin A. M., Terechin Yu.V.). Kiev: Naukova dumka: 252p. (in Russian).

Medit. Mar. Sci., 2/1, 2001, 69-77
DEALLO, E.P., 1966. Zooplankton in the eastern part of the Mediterranean Sea (Levantine and Syrtis Seas). Investigation of Plankton in the Southern seas. Moscow, 7: 62-81 (in Russian).

FEDORINA, A.J., 1978. Dynamics of the Black Sea zooplankton development and reasons causing it // VNIRO. - Moscow - 49p. - Dep. In CNI TACRH 11.05.78. No.149 (in Russian).

GREZE, V.N., BOGUSLAVSKIY, S.G. & BELYAKOV, Yu.M., 1979. Principles of biological productivity of the Black Sea (eds. Greze V.N.).- Kiev: Naukova dumka: 391p. (in Russian).

GREZE, V.N., PAVLOVA, E.V., SHMELEVA, A.A. & DEALLO, E.P., 1982. Zooplankton of the eastern Mediterranean and its quantitative distribution. Ecologiya morya 8: 37-46 (in Russian).

GREZE, V.N., 1989. Pelagial of the Mediterranean Sea as ecological system. Kiev: Naukova dumka, 198p. (in Russian).

HURE, J., JANORA, A. & DI CARLO, B.S., 1980. Spatial and temporal distribution of copepod communities in the Adriatic Sea. J. of Plankton Research.2: 295-316.

KIDEYS, A.E., 1994. Recent dramatic changes in the Black Sea ecosystem: The reason for the sharp decline in Turkish anchovy fisheries. J Mar Sys 5: 171-181.

KIDEYS, A.E., GORDINA, A.D., BINGEL, F. & NIERMANN, U., 1999. The effect of environmental conditions on the distribution of eggs and larvae of anchovy (Engraulis encrasicolus L.) in the Black Sea. ICES J mar Sci 56: 58-64.

KIDEYS, A.E., KOVALEV, A.V., SHULMAN, G., GORDINA, A.D. & BINGEL, F., 2000. A review of zooplankton investigations of the Black Sea over the last decade. J Mar Sys 24:355-371.

KOVAL, L.G., 1984. Zoo- and macrozooplankton of the Black Sea. - Kiev: Naukova dumka, 141 (in Russian).

KOVALEV, A.V., 1991. Structure of zooplankton communities of the Atlantic and the Mediterranean basins. - Kiev: Naukova dumka, 141p. (in Russian)

KOVALEV, A.V. & SHMELEVA, A.A., 1982. Fauna of Copepoda in the Mediterranean Sea. Ecologia morya 8: 82-87 (in Russian).

KOVALEV, A.V., MELNIKOV, V.V., OSTROVSKAYA, N.A. & PRUSOVA, I.Yu., 1993. Macrozooplankton: Plankton of the Black Sea (eds. Kovalev A.V., Finenko Z.Z.) - Kiev: Naukova dumka: 183-193 (in Russian).
(Eastern Mediterranean), I. General aspects.
Oceanologica acta, 20: 521-535.
OVCHINNIKOV, I.M., PLAKHIN, E.A. & MOSKALENKO, L.V., 1976. Hydrology of the Mediterranean Sea. Moscow: Hydrometeoizdat: 375p. (in Russian).
PETIPA, T.S., SAZHINA, L.I. & DELALO, E.P., 1963. Distribution of zooplankton in the Black Sea in 1951-1956. Oceanology. 3: 110-129 (in Russian).
POLISCHUK, L.N., NASTENKO, E.V. & GARKAVAYA, G.P., 1984. Some peculiarities of modern state of pelagic and neustonic zoocenosis of the Black Sea. Ekologiya morya 18: 25-34 (in Russian).
SAZHINA, L.I., 1964. Seasonal changes of zooplankton in the north-western part of the Black Sea in 1957. Proc. of Sevastop. Biol. st., 17: 262-275 (in Russian).
SOROKIN, YU.I., 1982. The Black Sea: Nature resources. Moscow, Nauka, 216 p (in Russian).
ZAGORODNYAYA, YU.A., SKRYABIN, V.A., 1995. Current trends in the zooplankton evolution in the Black Sea coastal areas. Investigations of shelf zone of Azov-Black Seas basin. Nas Ukrain., MHI, Sevastopol: 87-95 (in Russian).
ZAITSEV, YU.P., 1992. Recent changes in the trophic structure of the Black Sea. Fisheries Oceanography, 1: 180-189.
ZAITSEV, YU.P. & ALEXANDROV, B.G., 1997. Recent man-made changes in the Black Sea. In: Ecosystem sensitivity to change: Black Sea, Baltic Sea and North Sea (eds. E. Oszoy & A. Mikaelyan). Kluwer Acad. Publ., 25-31.
ZENKEVICH, L.A., 1963. Biology of the seas of the USSR. Moscow: Publ. Ac. Sci. USSR, 739 p. (in Russian).
