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COMPOSITION, STRUCTURE, AND DYNAMICS OF COMMUNITIES OF FISH AND DECAPODS OFF THE SOUTHERN COAST OF THE CRIMEA (THE BLACK SEA)

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Under climatic and anthropogenic factors, the Black Sea ecosystem is being transformed and replenished with new species of fish and Decapoda. Therefore, regular monitoring studies become relevant which allow identifying the effect of these processes on biocenoses of the Crimean Peninsula coastal waters. The aim of this work was to investigate taxonomic, structural, and quantitative characteristics of decapods and ichthyofauna of the Black Sea in the area of the Cape Martyan nature reserve. To make the results more complete, both adult individuals and planktonic and larval stages were sampled and analyzed. Fish and decapods were sampled with fixed nets, bottom traps, and hand nets. Ichthyoplankton and Decapoda larvae were sampled with an ichthyoplankton cone-shaped net IKS-80. For decapods, a high level of species diversity was revealed: those were represented by 17 species from 14 families. Two species, *Alpheus dentipes* Guérin, 1832 and *Lysmata seticaudata* (Risso, 1816), were recorded in the study area for the first time. The taxonomic composition of ichthyofauna was formed by about 30 species, mostly benthic and demersal fish. The structure of fish communities was quite stable; there was a trend towards an increase in diversity, a decrease in the prevalence of certain species, and an overall improvement in their state. A rise in abundance of some Atlantic–Mediterranean species, such as *Serranus scriba* (Linnaeus, 1758) and *Chromis chromis* (Linnaeus, 1758), can serve as an indicator of variations in hydrological and hydrochemical parameters of the environment related to general climate and ecological changes. The values of the quantitative parameters of fish eggs and larvae, (76.3 ± 11.4) and (18.8 ± 4.6) ind.·m^{-2}, respectively, were sufficiently high for the Black Sea coastal waters. However, the proportion of living, normally developing fish eggs in the water area was low, 28.6% of the total. The data obtained can be used for comparative analysis during long-term monitoring in the Black Sea water area.

Keywords: Black Sea, ichthyofauna, ichthyoplankton, Decapoda, Cape Martyan nature reserve

One of the unique features of the Black Sea is a significant variety of its ecological conditions. This is driven by its internal location affecting its climate conditions and by the presence of a number of large and small rivers, with many of them being concentrated in a relatively small area. In this regard, the fauna of various spots of the coastal zone, even very close to each other, often has peculiarities related to both species composition and characteristics of hydrobionts: quantitative, ecological, and biological ones. According to the zoning carried out by V. Vodyanitsky [1949] for the shores of the Crimean Peninsula, the area of its southern coast stands out due to its natural-historical and zoogeographic features. Specifically, the coastal zone from Cape Aya to Feodosiya Bay is characterized by the maximum development of two main types of biotopes and related communities: rocky-stony and pebbly-boulder ones [Boltachev, Karpova, 2017]. Such a combination of biotopes is not reported for other areas of the Crimea, and it determines characteristic features of the composition of local fish communities. At the same time, up to 65% of the coastline is concreted, and only the vicinity of capes remains almost intact [Goryachkin, 2015]. Thus, the level of anthropogenic transformation of the coastal zone is very significant and continues to increase.

To date, typical underwater biocenoses in a relatively intact state can be found only in some sites of the coastal zone. One of them is the Cape Martyan protected water area. The Cape Martyan nature reserve was organized according to the Decree of the Council of Ministers of the Ukrainian SSR No. 84 dated 20.02.1973 with the aim of protecting typical terrestrial and aquatic natural complexes of the southern coast of the Crimea. The reserve water area borders two capes, Nikitin and Martyan. It has an area of 120 hectares, a width of 300–500 m, and a length of about 2,200 m along the shore [Marine Protected Areas of the Crimea, 2015].

The fact that these waters belong to protected areas ensured no fishing activities with coastal fixed fishing gear and a relatively low level of anthropogenic load.

Cape Martyan is a limestone massif consisting of marble-like limestones and cemented breccias that come ashore and are subject to intense wave abrasion [Yena et al., 2013]. The coastal zone is formed by alternating limestone entrances with steep cliffs up to 20 m high and narrow pebble beaches. Bottom underwater landscapes consist of block and boulder-block heaps and pebble-boulder sections of the surf zone near the shores. From a depth of 8 m and deeper, those are replaced by loose sandy deposits with admixtures of silt and shells. Water salinity is stable, 17–18‰. This area can serve as a testing ground for studying features of regional communities of marine fauna and long-term changes occurring there under natural and anthropogenic factors.

The first data on ichthyofauna of this water area provided information on the registration of 71 fish species [Boltachev et al., 2014]. Decapoda fauna, according to [Grintsov et al., 2008], was represented by only 5 species. However, researchers have never focused on the cenotic role of species, their distribution, abundance, structural characteristics of communities, and trends in their variations. To date, salinization and changes in the mean annual temperature are recorded in the Black Sea [Kazmin et al., 2010; Shaltout, Omstedt, 2014]. Over 10 years, the salinity growth averaged 0.0038‰ [Belokopytov, 2017]. The mean annual water temperature, according to observations of 1982–2015, increases every decade by an average of 0.64 °C [Sakalli, Basusta, 2018]. Variations in hydrological and hydrochemical parameters result from global climate changes, water influx from the Sea of Marmara, and a decrease in freshwater runoff from the mainland. These processes contribute to the natural dispersal of the fauna inhabiting the Mediterranean Basin and Indian Ocean [Boltachev et al., 2009; Oven, Salekhova, 1969; Pusanow, 1967; Puzanov, 1965; Vinogradov et al., 2017]. Taxonomic and structural characteristics of the coastal zone communities are undergoing certain changes. Since the regional features of these changes are closely related to the ecosystem characteristics of the sea coastal areas, local biocenosis is studied in detail. At the same time, transformations in species composition are often not indicative. With sufficiently long-term investigations, as well as the use of various methods of material sampling to level the selectivity of fishing gear, most species of the sea fauna come to the attention of researchers. Characteristic features and changes occurring in communities can be more reliably revealed based on the analysis of their structure and quantitative parameters.

The aim of this work is to assess the current state of coastal communities of fish and decapods, to analyze the cenotic role of species in the Cape Martyan vicinity, and to determine their abundance in order to reveal changes in communities and processes of fish reproduction occurring in this area under various environmental factors.

MATERIAL AND METHODS

The work is based on material sampled in expeditions during the warm period of several years (May–July 2010, 2011, and 2013; July–September 2019) in the Cape Martyan vicinity and in the Cape Martyan protected water area (Fig. 1).

Fig. 1. The study area, Cape Martyan protected water area (the points indicate sampling locations)

Fish and decapods were sampled with fixed single-walled nets, bottom traps, and hand nets. We used nets with a length of 30 m, a canvas height of 1.8 m, and a mesh of 15, 20, 25, 35, and 45 mm. Sampling was carried out at various depths, both perpendicular and parallel to the shore. The depth of net setting varied within 1–8 m; nets were set up overnight, 20:00 to 07:00. Bottom traps, with a mesh of 6–8 mm, were set up at depths of 1–2 m. Sampling was followed by the analysis of catches: the species were identified; the abundance and weight of individuals of each species of hydrobionts were determined.

Ichthyoplankton and Decapoda larvae were sampled in July 2019 at 10 stations in the nature reserve and adjacent water area (Fig. 1, Table 1). Coastal stations were located at a distance of 130–160 m from the water edge; offshore stations, at a distance of 300–500 m. Depths ranged within 5–16 m. At each station, vertical sampling from the bottom to the surface was carried out with an ichthyoplankton cone-shaped net IKS-80, with mesh of 400 μm and the inlet area of 0.5 m^2. The temperature of the surface water horizon was measured; during our work, it was +23.0…+25.0 °C. The coordinates of the boat position were recorded.

To determine the actual depth of the net immersion, the angle of deviation from the vertical of the cable was measured at the lower position of the net. In the calculation, the following formula was used:

$$b = c \times cos a ,$$

where b is the depth of the actual immersion of the net;

c is the length of the etched cable;

a is the angle of deviation of the cable from the vertical.

Table 1. Plankton sampling in the nature reserve waters and in the adjacent water area, 17.07.2019

Station number	Coordinates	Depth, m	Station number	Coordinates	Depth, m
1	44°30′14.5″N, 34°14′18.4″E	8	6	44°30′11.6″N, 34°15′7.2″E	16
2	44°30′3.5″N, 34°14′26.3″E	14	7	44°30′24.6″N, 34°15′28.8″E	16
3	44°30′3.2″N, 34°14′43.6″E	15	8	44°30′30.5″N, 34°15′19.8″E	6
4	44°30′15.0″N, 34°14′43.8″E	10	9	44°30′40.6″N, 34°15′49.3″E	14
5	44°30′17.8″N, 34°14′58.9″E	6	10	44°30′42.1″N, 34°15′42.1″E	5

The identification of species of hydrobionts and the order of taxa arrangement are given according to modern concepts [Catalog of Fishes, 2021; Vasil'eva, 2007].

Ichthyoplankton species were determined in accordance with T. Dekhnik [1973] and E. Kalinina [1976].

Diversity indices for communities of fish and decapods were calculated according to Yu. Odum [1986]:

- Shannon species diversity index, $H = -\Sigma P_i \times \log_2 P_i$;
- Margalef species richness index, $D = (S - 1) / \lg N$;
- Simpson dominance index, $c = \Sigma(n_i / N)^2$;
- Pielou evenness index, $e = H / \log S$.

RESULTS

Ichthyofauna. Sixteen fish species belonging to 9 orders and 14 families were identified in net catches in the coastal water area. Out of them, Labridae was the most diverse family (three species). Other families were represented by one species each (Table 2).

Table 2. Species composition and proportion of fish in net catches

Family	Species	Mean abundance of fish in catches, %	
		2010–2013	2019
Dasyatidae	*Dasyatis pastinaca* (Linnaeus, 1758)	0	0.5
Lotidae	*Gaidropsarus mediterraneus* (Linnaeus, 1758)	1.2	1.1
Mugilidae	*Chelon auratus* (Risso, 1810)	3.6	0
Scorpaenidae	*Scorpaena porcus* Linnaeus, 1758	42.0	27.4
Serranidae	*Serranus scriba* (Linnaeus, 1758)	0	8.1
Carangidae	*Trachurus mediterraneus* (Steindachner, 1868)	1.2	19.4
Sparidae	*Diplodus annularis* (Linnaeus, 1758)	1.8	2.7
Sciaenidae	*Sciaena umbra* Linnaeus, 1758	2.4	0.5
Mullidae	*Mullus barbatus ponticus* Essipov, 1927	1.8	6.5
Pomacentridae	*Chromis chromis* (Linnaeus, 1758)	0	10.8
Labridae	*Symphodus ocellatus* (Linnaeus, 1758)	1.8	1.6
	Symphodus roissali (Risso, 1810)	13.0	11.8
	Symphodus tinca (Linnaeus, 1758)	23.7	7.5
Uranoscopidae	*Uranoscopus scaber* Linnaeus, 1758	1.2	1.1
Blenniidae	*Parablennius sanguinolentus* (Pallas, 1814)	5.3	1.1
Gobiidae	*Ponticola eurycephalus* (Kessler, 1874)	1.2	0

In the study area, the basis of fish communities during the summer period were sedentary species (the ones that do not perform significant migrations). It was mainly *Scorpaena porcus*, but there were several Labridae representatives as well: *Symphodus tinca* and *S. roissali*. Such a combination is quite common for rocky and stony biotopes of the Black Sea coastal zone. Abundance of mass migratory species is subject to significant interannual variability. In 2010, 2011, and 2013, *Trachurus mediterraneus* accounted for slightly more than 1% in catches, while in 2019, the proportion of this species reached 19.4%. The proportion of *Mullus barbatus ponticus* varied within 1.6–6.8% in different years.

Unusual trends were revealed for *Serranus scriba* and *Chromis chromis*. Previously, these species were rare, especially the first one. At present, according to our data, their abundance noticeably increased. In 2019, their proportions in catches amounted to 8.1 and 10.8%, respectively. Such a high abundance of these species is more characteristic of the Mediterranean Sea than of the Black Sea.

All registered species are typical allochthonous representatives of marine fauna, except for *Ponticola eurycephalus* belonging to the autochthonous Ponto-Caspian group.

The quantitative indicators of catches (catch *per* unit effort) are provided in Table 3.

Table 3. Catch *per* unit effort for nets with various mesh size by abundance (ind.·h^{-1}) and biomass (kg·h^{-1}) of fish species recorded in the water area of the Cape Martyan nature reserve

Species	Net mesh size, mm				
	15	22	24	35	45
Dasyatis pastinaca (Linnaeus, 1758)					0.09 0.018
Chromis chromis (Linnaeus, 1758)	2.69 0.033				
Sciaena umbra Linnaeus, 1758				0.09 0.016	
Diplodus annularis (Linnaeus, 1758)		0.09 0.006		0.36 0.051	
Serranus scriba (Linnaeus, 1758)	0.41 0.010	0.09 0.006	0.18 0.020	0.09 0.019	0.18 0.033
Mullus barbatus ponticus Essipov, 1927	0.05 0.019	0.09 0.005			
Trachurus mediterraneus (Steindachner, 1868)	1.41 0.034	0.18 0.013	0.27 0.023		
Scorpaena porcus Linnaeus, 1758	0.95 0.216	1.18 0.153	0.45 0.035	0.91 0.173	0.18 0.015
Symphodus tinca (Linnaeus, 1758)	0.27 0.028	0.09 0.008	0.55 0.041	0.09 0.014	
Symphodus ocellatus (Linnaeus, 1758)	0.14 0.001			0.18 0.001	
Symphodus roissali (Risso, 1810)	1.32 0.020	0.36 0.015			
Uranoscopus scaber Linnaeus, 1758				0.18 0.034	
Gaidropsarus mediterraneus (Linnaeus, 1758)	0.09 0.003				
Parablennius sanguinolentus (Pallas, 1814)	0.9 0.002	0.09 0.003			

Note: above the line, abundance; below the line, biomass.

In plankton samples of the Cape Martyan water area, eggs and larvae of 14 fish species were registered (Table 4). All species were previously noted in ichthyofauna of this nature reserve [Boltachev et al., 2014]. They all spawn in summer, and their eggs and larvae are characteristic of coastal waters of the Crimea at the peak of the warm season [Dekhnik, 1973].

Table 4. Ichthyoplankton species composition for all the stations

Species	Abundance, ind.		Proportion, %	
	Eggs	Larvae	Eggs	Larvae
Engraulis encrasicolus (Linnaeus, 1758)	286	63	64.0	56.3
Chelon auratus (Risso, 1810)	1	0	0.2	0.0
Serranus scriba (Linnaeus, 1758)	1	0	0.2	0.0
Pomatomus saltatrix (Linnaeus, 1766)	1	0	0.2	0.0
Trachurus mediterraneus (Steindachner, 1868)	106	11	23.7	9.8
Diplodus annularis (Linnaeus, 1758)	18	6	4.0	5.4
Sparidae gen. sp.	1	0	0.2	0.0
Sciaena umbra Linnaeus, 1758	1	0	0.2	0.0
Mullus barbatus ponticus Essipov, 1927	25	3	5.6	2.7
Symphodus cinereus (Bonnaterre, 1788)	0	1	0.0	0.9
Trachinus draco Linnaeus, 1758	2	0	0.4	0.0
Uranoscopus scaber Linnaeus, 1758	2	0	0.4	0.0
Pomatoschistus minutus (Pallas, 1770)	–	1	–	0.9
Gobius niger Linnaeus, 1758	–	2	–	1.8
Gobiidae gen. sp.	–	1	–	–
Arnoglossus kessleri Schmidt, 1915	2	0	0.4	0.0
Damaged or unidentifiable	1	24	0.2	21.4
In total	**447**	**112**	**100.0**	**100.0**

Out of the species recorded, *Engraulis encrasicolus* was the most abundant one, but proportions of its eggs and larvae were less significant than those indicated in literature for the Black Sea coastal area off the Crimea at the peak of summer spawning. Specifically, on the Crimean shelf in July 2010, the European anchovy eggs and larvae accounted for 83.0 and 60.0% of the total, respectively [Klimova et al., 2014]. In July–August 2019, the proportion of anchovy eggs in samples was 85.0%, while the proportion of larvae was 77.0% [Klimova et al., 2020].

During the period of sampling, out of 286 anchovy eggs, 285 specimens (99.6%) were at the early stages of development: up to the stage III inclusive, according to T. Dekhnik [1973]. One living egg was at the late stage of development, the stage V. The proportion of dead anchovy eggs was 83.2%, while that of living, normally developing eggs was 16.8%.

The European anchovy prelarvae and larvae had a total length range of 1.7–5.2 mm (on fixed material). The total length of 60 specimens constituting the vast majority (95.2%) was of ≤ 3.5 mm.

Eggs of other fish species accounted for 36.0% of the total; larvae accounted for 43.7%. The most frequently found species, as expected during the summer spawning season, were the horse mackerel (23.7% of eggs and 9.8% of larvae of the total; the proportion of living eggs was 51.9%), the red mullet (5.6 and 2.7%, respectively; 36.0% of living eggs), and the annular seabream (4.0 and 5.4%, respectively; 50.0% of living eggs).

Unexpectedly large, 21.4% of the total abundance of larvae and prelarvae, was the proportion of specimens inaccessible for species identification. Those were small and the smallest larvae and prelarvae, with the total length of 1.05–1.75 mm. Many of them retained their embryonic form and had no features characteristic of postembryonic development which are necessary to identify the species. In our opinion, their occurrence in sampled material did not result from damage and destruction of eggs at the final stages of development during sampling and fixation. In this case, the proportion of eggs with mechanical damage would be noticeable, and there would be membranes of destroyed eggs in samples. In fact, we noted one destroyed egg of unidentifiable species, while empty membranes were not found at all.

Decapoda. In the summer 2019, we investigated decapod fauna in coastal waters of the Cape Martyan nature reserve. Larvae and adult specimens of 11 Decapoda species representing 9 families were identified.

Larvae of 10 decapod species were recorded in the study area. Their mean abundance was 55.2 ind.·m^{-2} (Table 5). In plankton samples, larvae of *Pilumnus hirtellus* (23.6%), *Clibanarius erythropus* (20.7%), *Hippolyte leptocerus* (20.3%), *Athanas nitescens* (18.5%), and *Pachygrapsus marmoratus* (5.1%) prevailed. Larvae of other decapods were found singly. In addition to larvae of the species previously known for the water area [Khajlenko, 2019], we registered larvae of shrimps rare for the Crimean waters: *Alpheus dentipes* and *Lysmata seticaudata*.

Table 5. Species composition and abundance of Decapoda planktonic larvae in the water area of the Cape Martyan nature reserve

Species	Abundance, ind.·m^{-2}
Athanas nitescens (Leach, 1814 [in Leach, 1813–1815])	10.2
Alpheus dentipes Guérin, 1832	1.4
Lysmata seticaudata (Risso, 1816)	0.4
Hippolyte leptocerus (Heller, 1863)	11.2
Palaemon elegans Rathke, 1836	1.4
Clibanarius erythropus (Latreille, 1818)	11.4
Pisidia longimana (Risso, 1816)	1.8
Pachygrapsus marmoratus (J. C. Fabricius, 1787)	2.8
Xantho poressa (Olivi, 1792)	1.6
Pilumnus hirtellus (Linnaeus, 1761)	13.0
In total	**55.2**

In the study area, adult decapods were represented by 9 species. Out of them, *Eriphia verrucosa* (Forskål, 1775), *P. marmoratus*, *Xantho poressa*, and *Palaemon elegans* are common. *A. nitescens*, *Pisidia longimana*, and *C. erythropus* were found in significant numbers. Out of rare species, *H. leptocerus* and *P. hirtellus* were recorded. All Decapoda representatives registered in the nature reserve waters were distributed in communities of hard bottom sediments from the surface down to a depth of 5–10 m.

DISCUSSION

The taxonomic composition of ichthyofauna in the study area was formed by about 30 species, mainly benthic fish (*S. porcus*, *P. eurycephalus*, and Blenniidae representatives) and demersal ones (Labridae, Sparidae, *etc.*). In different years, their indicators of relative abundance were characterized by significant variability. However, throughout the investigated period, diversity parameters of communities in general remained quite stable (Table 6).

Table 6. Diversity indices for communities of fish and Decapoda in the water area of the Cape Martyan nature reserve

Index	Fish					Decapoda
	2010	2011	2013	2019		2019
				Fish	Ichthyoplankton	
Shannon species diversity index, *H*	2.45	2.08	2.12	2.40	1.56	2.73
Margalef species richness index, *D*	7.25	7.65	7.40	5.73	5.50	4.74
Simpson dominance index, *c*	0.25	0.36	0.27	0.14	0.48	0.18
Pielou evenness index, *e*	0.64	0.55	0.56	0.63	0.39	0.82

Data for quantitative studies of decapod communities were obtained for the first time. Accordingly, there is no material to compare with. Based on data of plankton surveys, the main indicators of species diversity were calculated (see Table 6). The established values of the Shannon species diversity index and distribution of the relative abundance expressed by the Pielou evenness index characterize the water area as the one with a relatively low species richness of Decapoda representatives. The low value of the Simpson dominance index indicates the absence of obvious dominants more precisely than values of other indices reflecting the presence of prevailing species.

Based on the analysis of the dominance–diversity curve for fish communities (Fig. 2), it can be concluded that there is a trend towards an increase in diversity, a decrease in the prevalence of certain species, and a general complication of community structure. Apparently, a rise in *S. scriba* abundance in net catches (the species previously extremely rare for the Black Sea fauna) can serve as an indicator of variations in hydrological and hydrochemical parameters of the environment resulting from general climate and environmental changes. An increase in *S. scriba* abundance is confirmed by visual underwater observations as well.

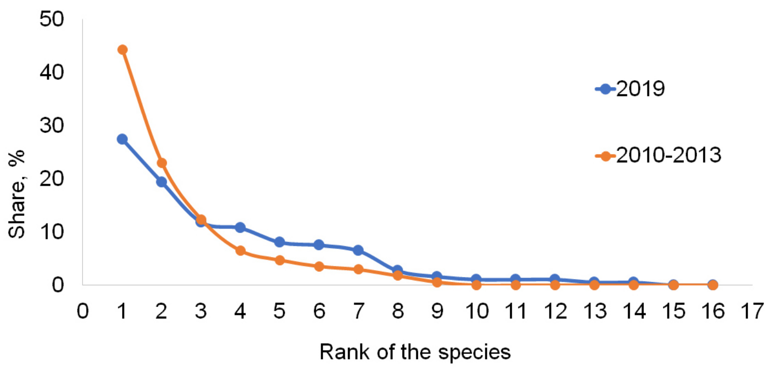

Fig. 2. Ranking of the fish species of the study water area by abundance: along the abscissa axis, the serial number of the species (species are arranged in descending order of their abundance); along the ordinate axis, the proportion of this species in the catch by abundance

The proportion of living, normally developing fish eggs in the water area, 28.6% of the total, is to be analyzed further. For example, in summer, under similar conditions (in the open sea, at coastal stations opposite Sevastopol, 250–500 m off the coast, above a depth of 10–19 m, and against the backdrop of the sea surface temperature of +20.0…+25.3 °C), the proportion of dead eggs was 55.2%, while that of living, normally developing eggs was 44.8%.

In 2002–2008, according to literature data, the proportion of dead eggs in the coastal sea area from the Sevastopol Bay to the 2-mile zone averaged 63.1% [Klimova, 2010]. The proportion of living eggs amounted to 36.9%. Importantly, this analysis refers to both summer- and winter-spawning fish species and is based on the study of samples both from the coastal area of the open sea and the innermost spot of the Sevastopol Bay, where the proportion of dead eggs was the highest [Klimova, 2010].

In ichthyoplankton of the study water area, the European anchovy was the prevailing species at the time of sampling, but proportions of its eggs and larvae were lower than those provided in literature for the Black Sea coastal water area off the Crimea in midsummer. Specifically, on the Crimean shelf in July 2010, anchovy eggs and larvae accounted for 83 and 60% of the total, respectively [Klimova et al., 2014]. In July 2017, the proportion of anchovy eggs off the Crimean coast was 77% [Klimova et al., 2021]. In July–August 2019, on the shelf off the coast of the Crimea and Russian Caucasus, the proportion of anchovy eggs in samples was 85%, and the proportion of larvae was 77% [Klimova et al., 2020].

The occurrence of anchovy eggs in samples taken at the peak of spawning in the first half of the day at the early (prevailing) and final (with much lower abundance) stages of development against the backdrop of the actual absence of eggs at the intermediate stage is described in literature [Dekhnik, 1973]. It is the norm, and it is due to features of the daily anchovy reproduction rhythm. However, our data show not only a lower proportion of eggs at the later stages of development, but their virtually complete absence, which does not correspond to the norm. The recorded proportion of dead anchovy eggs, 83.2%, significantly exceeded that noted for the Crimean shelf in July 2010, 74.0% [Klimova et al., 2014]. Living eggs are easily distinguished from dead ones; the death of eggs occurs in the sea and is not related to sampling and fixation. Thus, based on information on the proportion of living eggs in a sample, one can conclude on the degree of survival of embryos at a given stage of the development under certain conditions [Dementjeva, 1958]. Knowing the timing of the development of embryos and larvae at a given temperature, it is possible to monitor the development of each generation by abundance of survived embryos and corresponding groups of larvae, depending on their size and growth and based on the numerical prevalence of a particular group of larvae by stages of development.

In our material, the ratio of the abundance of the European anchovy prelarvae and larvae (in total, 63 ind.) to the total abundance of eggs of this species was significant, 22.0%. For the Crimean shelf in July 2010, the value was only 16.1% [Klimova et al., 2014]. Almost all of them, 95.2%, were the ones at the prelarvae stage or larvae at the earliest stage of development, on yolk feeding [Klimova et al., 2020], and were no more than a day old [Dekhnik, 1973]. Anchovy prelarvae, due to their small size (primarily body height), mostly drop out of catches, and their abundance may be underestimated by us. But even high abundance of prelarvae and a high value of the ratio of their abundance to the abundance of eggs cannot serve as an unambiguous indicator of effective spawning. According to [Productivity of the Black Sea, 1979], the mortality of anchovy is relatively low at the late stages of embryogenesis, sharply increases during the transition from embryonic to postembryonic development, and remains high throughout the entire stage of yolk feeding (a group of larvae 2.0–3.4-mm long which includes almost all anchovy larvae caught by us). With transition to mixed feeding (anchovy larvae 3.5–6.0-mm long), mortality sharply decreases again. However, only 4.8% of larvae we recorded survived and fell into this group. We did not reveal any older larvae.

Attention is to be drawn to the proportion of abnormally small and minute fish larvae and prelarvae that cannot be identified down to the species level, 21.4% of the total abundance of those in our material. The relationship between the size and general development of hatching fish larvae and water temperature is known. Specifically, for the European anchovy, it is shown that embryos hatch more developed and bigger in size at a lower temperature [Dekhnik, 1973]. By itself, the surface water temperature of the study area was not extremely high for the season; in our opinion, the reason for the observed phenomenon was not the absolute value of the temperature of the environment, but its dynamics. The negative effect of fluctuations in temperature and its deviation from optimal range at the late stages of development of eggs and early stages of postembryonic development of fish was described in detail in relation to cultivated and artificially reproduced freshwater species [Portnaya et al., 2015]. In this case, routine procedures are monitoring of the state of the environment and analysis of the dynamics of embryonic and postembryonic fish development. With an abrupt increase in the temperature of the environment during the course of embryogenesis, researchers observed early hatching, developmental anomalies, and the death of fish prelarvae and larvae even against the backdrop of optimal values of other significant factors [Portnaya et al., 2015].

According to the environmental data available at http://weatherarchive.ru [2020], in June 2019, the mean surface water temperature off the coast of Yalta (the spot of constant observation closest to the study area) was the highest for 2010–2020 and amounted to +23.2 °C. The mean temperature in July 2019, on the contrary, was the minimum over the same long period and amounted to +23.8 °C. Analysis of the satellite data archive on temperature and state of the Black Sea surface water [Arkhiv dannykh, 2022] confirms this fact. So, in July 2019, on the day of our work and on some previous days, off the southern coast of the Crimea, in particular in the study area, there were spots with the surface water temperature 1–3 °C lower than the values for adjacent open waters. For the study water area on the day of sampling, the same source showed the presence of a current directed to the coast, with a flow rate of 0.10–0.15 $m \cdot s^{-1}$. The surface temperature was of +23.0…+25.0 °C. Such a range is unusual for a small water area and may indicate the process of mixing of heated surface waters with underlying cold ones near the coast. Apparently, water mixing and variations in its temperature were a stress factor, affected the development of eggs and their survival, and caused early hatching of incompletely formed prelarvae.

The observed abundance of fish eggs and larvae, (76.3 ± 11.4) and (18.8 ± 4.6) $ind. \cdot m^{-2}$, respectively, can be considered significantly high for the Black Sea coastal area off the Crimea in July. In general, the values correspond to expected ones. For example, on the shelf off the Crimean coast from Cape Karadag to Cape Tarkhankut in July 2010, the mean abundance of eggs was 46.2 $ind. \cdot m^{-2}$, and of fish larvae, 10.1 $ind. \cdot m^{-2}$ [Klimova et al., 2014]. For the shelf opposite Yalta, the same literature source provides significantly lower estimates of ichthyoplankton abundance, 21.0 $ind. \cdot m^{-2}$ for eggs and 1.9 $ind. \cdot m^{-2}$ for fish larvae. In July 2017, on the shelf off the Crimea, the mean abundance of eggs was 25.0 $ind. \cdot m^{-2}$, and of fish larvae, 3.2 $ind. \cdot m^{-2}$ [Klimova et al., 2021].

According to literature data, 15 Decapoda species were recorded in the nature reserve waters and in the adjacent water area [Grintsov et al., 2008; Khajlenko, 2019].

The first information on Decapoda fauna in the Cape Martyan area dates back to 1976. Then, the most complete inventory of the fauna of hydrobionts for the coastal zone of the nature reserve and adjacent waters down to depths of 10–15 m was carried out. According to it, 13 species of decapods were noted: *A. nitescens*; *Palaemon adspersus* Rathke, 1836; *Upogebia pusilla* (Petagna, 1792); *P. longimana*; *Diogenes pugilator* (P. Roux, 1829); *C. erythropus*; *E. verrucosa*; *Carcinus aestuarii* Nardo, 1847; *Liocarcinus depurator* (Linnaeus, 1758); *P. marmoratus*; *X. poressa*; *P. hirtellus*; and *Macropodia czernjawskii* (Brandt, 1880) [Khajlenko, 2019].

The next stage of comprehensive studies on the species diversity of benthic invertebrates and meroplankton of the upper sublittoral zone in the nature reserve was performed in the summer season of 2004–2006. According to its results, five representatives of the order were recorded; out of them, one species, *H. leptocerus*, was reported for the fauna of the nature reserve for the first time [Grintsov et al., 2008]. Moreover, the cited paper provides data on the registration of single larvae of *A. nitescens* in plankton.

In 2017, preliminary data were obtained on the assessment of the current state of decapod fauna in the coastal zone of the nature reserve at depths of 0–2 m [Khajlenko, 2019]. According to it, in the study water area, Decapoda was represented by four species. *P. elegans* was not previously recorded in the coastal aquatic complex.

Summarizing the lists of species published for this area and our data, we can conclude as follows: Decapoda fauna in the coastal water area of the Cape Martyan nature reserve includes at least 17 species representing 14 families. Interestingly, nine species are common, six species (*P. adspersus*, *U. pusilla*, *D. pugilator*, *C. aestuarii*, *L. depurator*, and *M. czernjawskii)* are known only from literature sources, and two species (*A. dentipes* and *L. seticaudata*) are new for the protected water area [own data].

Differences in species composition are primarily due to the confinement of species to different biotopes. Specifically, *D. pugilator*, *C. aestuarii*, and *Liocarcinus vernalis* (Risso, 1827), not registered by us, are found in open spots of soft soils (silt, sand, and shell). *U. pusilla* burrows in dense, soft ground. *P. adspersus*, *D. pugilator*, *C. aestuarii*, and *M. czernjawskii* are recorded in thickets of *Zostera* and other macrophytes growing on soft soils. In the water area of the nature reserve, this type of substrates is either absent or represented by local spots; this allows us to assume that the occurrence of some species of hydrobionts is related to characteristic bottom biotopes of waters adjacent to the protected water area.

Two shrimps, *A. dentipes* and *L. seticaudata*, whose larvae were recorded in our plankton samples, are very rare due to their extremely secretive lifestyle. These are cryptobenthic species, and their life cycle is confined to biotopes formed by various species of bivalves or to pretty similar spots of the bottom (caves, grottoes, *etc.*).

Thus, for the first time for a typical water area of the southern coast of the Crimean Peninsula, the current state of communities of fish and Decapoda was analyzed, alpha-diversity indicators were described, and characteristics of the abundance of cenosis-forming species were obtained. All these data can be used as a starting point for monitoring changes in the biocenosis of the water area.

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REFERENCES

1. *Arkhiv dannykh po Chernomy moryu* // Marine Portal / Marine Hydrophysical Institute : [site]. (in Russ.). URL: http://dvs.net.ru/mp/data/main_ru.shtml [accessed: 15.12.2022].
2. Belokopytov V. N. *Klimaticheskie izmeneniya gidrologicheskogo rezhima Chernogo morya.* [dissertation]. Sevastopol, 2017, 377 p. (in Russ.)
3. Boltachev A. R., Karpova E. P. *Marine Fishes of the Crimean Peninsula.* 2nd ed., revised & enlarged. Simferopol : Biznes-Inform, 2017, 376 p. (in Russ.). https://repository.marine-research.ru/handle/299011/1356
4. Boltachev A. R., Karpova E. P., Danilyuk O. N. Findings of new and rare fish species in the coastal zone of the Crimea (the Black Sea). *Journal of Ichthyology*, 2009, vol. 49, iss. 4, pp. 277–291. https://doi.org/10.1134/S0032945209040018
5. Boltachev A. R., Karpova E. P., Danilyuk O. N. List of fish species in nature-reserve "Cape Martyan". *Nauchnye zapiski prirodnogo zapovednika "Mys Mart'yan"*, 2014, iss. 5, pp. 113–121. (in Russ.)
6. *Catalog of Fishes: Genera, Species, References* / R. Fricke, W. N. Eschmeye, R. Van der Laan (Eds) : site. URL: https://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp [accessed: 12.01.2021].
7. Dekhnik T. V. *Ikhtioplankton Chernogo morya.* Kyiv : Naukova dumka, 1973, 235 p. (in Russ.). https://repository.marine-research.ru/handle/299011/5654

8. Dementjeva T. F. Methods of studying the effect of environmental factors on the fluctuations in the abundance of the Azov anchovy. *Trudy VNIRO*, 1958, vol. 34, pp. 30–62. (in Russ.)
9. Goryachkin Yu. N. Problems of nature management in the coastal zone of the Crimean Peninsula. *Ekologicheskaya bezopasnost' pribrezhnoi i shel'fovoi zon morya*, 2015, no. 1, pp. 5–11. (in Russ.)
10. Grintsov V. A., Lisitskaya E. V., Murina V. V. New data on the invertebrates fauna of the coastal zone of the "Cape Martjan" reservation (the Black Sea). *Ekologiya morya*, 2008, iss. 75, pp. 53–57. (in Russ.). https://repository.marine-research.ru/handle/299011/4800
11. Kalinina E. M. *Razmnozhenie i razvitie azovo-chernomorskikh bychkov*. Kyiv : Naukova dumka, 1976, 119 p. (in Russ.). https://repository.marine-research.ru/handle/299011/5659
12. Kazmin A. S., Zatsepin A. G., Kontoyiannis H. Comparative analysis of the long-term variability of winter surface temperature in the Black and Aegean seas during 1982–2004 associated with the large-scale atmospheric forcing. *International Journal of Climatology*, 2010, vol. 30, iss. 9, pp. 1349–1359. https://doi.org/10.1002/joc.1985
13. Khajlenko E. V. Materials for the study of invertebrates in "Cape Martyan" nature reserve. *Nauchnye zapiski prirodnogo zapovednika "Mys Mart'yan"*, 2019, iss. 10, pp. 115–129. (in Russ.). https://doi.org/10.36305/2413-3019-2019-10-115-129
14. Klimova T. N. Ichthyoplankton in coastal waters of southwestern Crimea in 2002–2008. *Morskoj ekologicheskij zhurnal*, 2010, vol. 10, no. 1, pp. 39–52. (in Russ.). https://repository.marine-research.ru/handle/299011/1053
15. Klimova T. N., Subbotin A. A., Vdodovich I. V., Zagorodnyaya Yu. A., Podrezova P. S., Garbazei O. A. Distribution of ichthyoplankton in relation to specifics of hydrological regime off the Crimean coast (the Black Sea) in the spring–summer season 2017. *Journal of Ichthyology*, 2021, vol. 61, iss. 2, pp. 259–269. https://doi.org/10.1134/S0032945221020077
16. Klimova T. N., Vdodovich I. V., Podrezova P. S., Dotsenko V. S., Kurshakov S. V., Zavyalov A. V. Vidovoe raznoobrazie, prostranstvennoe raspredelenie i troficheskie vzaimootnosheniya ikhtioplanktona Chernogo morya v letnii nerestovyi sezon 2019 g. In: *Nazemnye i morskie ekosistemy Prichernomor'ya i ikh okhrana* : sbornik tezisov II Vserossiiskoi nauchno-prakticheskoi shkoly-konferentsii, 28 September – 02 October, 2020, Kurortnoe, Feodosiya, the Republic of Crimea, RF. Sevastopol : FGBNU "Institut prirodno-tekhnicheskikh sistem", 2020, pp. 95–97. (in Russ.)
17. Klimova T. N., Vdodovich I. V., Zagorodnyaya Yu. A., Ignatyev S. M., Malakhova L. V., Dotsenko V. S. Ichthyoplankton in the plankton community of the Crimean Peninsula shelf zone (Black Sea) in July 2010. *Journal of Ichthyology*, 2014, vol. 54, iss. 6, pp. 409–421. https://doi.org/10.1134/S0032945214030060
18. *Marine Protected Areas of the Crimea* : scientific handbook. Simferopol : N.Orianda, 2015, 312 p. (in Russ.). https://doi.org/10.21072/978-5-9907290-3-2
19. Odum Yu. *Ekologiya* : in 2 vols / V. E. Sokolov (Ed.) ; transl. from English. Moscow : Mir, 1986, vol. 2, 376 p. (in Russ.)
20. Oven L. S., Salekhova L. P. On the problems of mediterranization of ichthyofauna of the Black Sea. *Gidrobiologicheskii zhurnal*, 1969, vol. 5, no. 4, pp. 124–127. (in Russ.). https://repository.marine-research.ru/handle/299011/10946
21. *Productivity of the Black Sea* / V. N. Greze (Ed.). Kyiv : Naukova dumka, 1979, 392 p. (in Russ.). https://repository.marine-research.ru/handle/299011/8059
22. *Prognoz i arkhiv pogody* : [site]. URL: http://weatherarchive.ru/ [accessed: 15.12.2020].
23. Portnaya T. V., Portnoy A. I., Sopot A. A. Character of embryonic and postembryonic development of rainbow trout while completing incubation of fish roe under conditions of detrimental rise in water temperature. *Zhivotnovodstvo i veterinarnaya meditsina*, 2015, no. 2 (17), pp. 26–33. (in Russ.)
24. Pusanow I. I. Mediterranization of the Black Sea fauna and perspectives of its intensification. *Zoologicheskii zhurnal*, 1967, vol. 46, iss. 9, pp. 1287–1297. (in Russ.)
25. Puzanov I. I. Successive stages of mediterranization

of Black Sea fauna. New data. *Gidrobiologicheskii zhurnal*, 1965, vol. 1, no. 2, pp. 54. (in Russ.)
26. Sakalli A., Basusta N. Sea surface temperature change in Black Sea under climate change: A simulation of the sea surface temperature up to 2100. *International Journal of Climatology*, 2018, vol. 38, iss. 13, pp. 4687–4698. https://doi.org/10.1002/joc.5688
27. Shaltout M., Omstedt A. Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. *Oceanologia*, 2014, vol. 56, iss. 3, pp. 411–443. https://doi.org/10.5697/oc.56-3.411
28. Vasil'eva E. D. *Ryby Chernogo morya. Opredelitel' morskikh, solonovatovodnykh, evrigalinnykh i prokhodnykh vidov s tsvetnymi illyustratsiyami, sobrannymi S. V. Bogorodskim.* Moscow : VNIRO, 2007, 238 p. (in Russ.)
29. Vinogradov A. K., Bogatova Yu. I., Sinegub I. A., Khutornoi S. A. *Ekologicheskie zakonomernosti raspredeleniya morskoi pribrezhnoi ikhtiofauny (Chernomorsko-Azovskii bassein).* Odesa : Astroprint, 2017, 416 p. (in Russ.)
30. Vodyanitsky V. A. O estestvennoistoricheskom raionirovanii Chernogo morya i, v chastnosti, u beregov Kryma. *Trudy Sevastopol'skoi biologicheskoi stantsii*, 1949, vol. 7, pp. 249–255. (in Russ.). https://repository.marine-research.ru/handle/299011/5295
31. Yena V. G., Yena A. V., Yena A. V. *Zapovednye landshafty Tavridy* : 2nd ed., revised & enlarged. Simferopol : Biznes-Inform, 2013, 427 p. (in Russ.)

СОСТАВ, СТРУКТУРА И ДИНАМИКА СООБЩЕСТВ РЫБ И ДЕСЯТИНОГИХ РАКООБРАЗНЫХ У ЮЖНОГО ПОБЕРЕЖЬЯ КРЫМА (ЧЁРНОЕ МОРЕ)

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Под влиянием климатических и антропогенных факторов экосистема Чёрного моря трансформируется и пополняется новыми видами рыб и десятиногих ракообразных, что обуславливает актуальность регулярных мониторинговых исследований, позволяющих выявить воздействие вышеназванных процессов на биоценозы прибрежных вод Крымского полуострова. Целью настоящей работы стало изучение таксономических, структурных и количественных характеристик сообществ декапод и ихтиофауны Чёрного моря в районе заповедника «Мыс Мартьян». Помимо зрелых организмов, в ходе работ были отобраны и проанализированы их планктонные личиночные стадии, что дополнило полученные результаты. Сбор рыб и десятиногих ракообразных осуществляли ставными сетями, донными ловушками и ручными сачками. Ихтиопланктон и личинок декапод облавливали планктонной сетью ИКС-80. Выявлен высокий уровень видового разнообразия десятиногих ракообразных, представленных 17 видами из 14 семейств. Два вида, *Alpheus dentipes* Guérin, 1832 и *Lysmata seticaudata* (Risso, 1816), отмечены для региона впервые. Таксономический состав ихтиофауны формируют около 30 видов, преимущественно донные и придонные рыбы. Структура сообществ рыб достаточно стабильна, отмечена тенденция к увеличению разнообразия, снижению доминирования отдельных видов и общему улучшению состояния. Рост численности некоторых атлантико-средиземноморских видов, таких как *Serranus scriba* (Linnaeus, 1758) и *Chromis chromis* (Linnaeus, 1758), может служить индикатором изменений гидрологических и гидрохимических параметров среды, связанных с глобальными климатическими и экологическими изменениями. Количественные характеристики икры и личинок рыб, (76,3 ± 11,4) и (18,8 ± 4,6) экз.·м$^{-2}$ соответственно, были достаточно высокими для прибрежных вод Чёрного моря, а доля живой, нормально развивающейся икры рыб в акватории — низкой, 28,6 % от общего количества. Полученные данные могут быть использованы для сравнительного анализа при многолетних мониторинговых работах в акватории Чёрного моря.

Ключевые слова: Чёрное море, ихтиофауна, ихтиопланктон, Decapoda, заповедник «Мыс Мартьян»