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State of the Ichthyoplankton Community along the Crimean Peninsula in August 2011

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Abstract—Data on species composition, spatial distribution of ichthyoplankton, and feeding of fish larvae in August 2011 are presented for the shelf and the open waters along the Crimean Peninsula from Kerch Strait to Karkinit Bay. In the ichthyoplankton, fish eggs and larvae represented 19 species from 16 families. The average egg abundance was 111 egg/m^2 and larvae abundance was 22 ind./m^2. The elimination ratio of the European anchovy *Engraulis encrasicolus*, which dominates in the plankton from the final stages of development to the prelarvae in 2011, was similar to that observed in 1957. The high number of larvae of the older age group in the western halistatic zone is explained by the peculiarities of the hydrological regime. Decrease in the pressure of predatory jelly macroplankton and an fodder zooplankton (zooplankton abundance) contribute to the survival of the fish larvae.

Keywords: ichthyoplankton, zooplankton, macroplankton, species composition, spatial distribution, survival rate, feeding of the fish larvae, Black Sea

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INTRODUCTION

In the 1990s, the ichthyoplankton of the Black Sea was characterized by extremely low abundance and species diversity. This was due to the large-scale development of the invader species ctenophore *Mnemiopsis leidyi* in the early 1990s; this situation persisted until the early 2000s (Klimova, 2005). In the late 1990s, another ctenophore, *Beroe ovata*, appeared in the Black Sea region, and *Mnemiopsis* was the main food object for this species. Large-scale development of *Beroe* in the 2000s significantly reduced the abundance and biomass of *Mnemiopsis*; this promoted the gradual restoration of the food base of the fish larvae (Shiganova et al., 2001; Klimova and Vdodovich, 2011). The studies of ichthyoplankton in the open sea areas along Crimea have not been carried out since the mid-1990s and were resumed only in 2010. The analysis of data collected in July 2010 indicates the restoration of the structure of the species composition of ichthyoplankton back to the pattern observed in the 1980s and notes the increase in the number of fish eggs compared with the 1990s (Klimova et al., 2014).

The study aims to analyze the species composition, spatial distribution, and the survival of fish eggs and larvae, as well as the feeding of larvae, and to assess the availability of their food in the open and shelf waters of the Crimean Peninsula in August 2011.

MATERIALS AND METHODS

The material was collected August 19–27, 2011, during the 70th cruise of R/V *Professor Vodyanitskii* in the open sea, on the continental slope, and at the shelf of the Crimean Peninsula (the Black Sea). Ichthyoplankton was sampled with a Bogorov-Rass net (BR-80/113, mesh size 400 μm). At the deep-water stations, sampling was performed at two water layers, 0–25 m and 0–100 m; at shallow areas, the trawling was performed for the whole water column from the bottom to the surface. The ichthyoplankton abundance at each station was calculated as the average of two trawls, since the abundance of the fish eggs and larvae varied insignificantly in the 0–25 and 0–100 m layers. Eggs and larvae were identified to the species level according to Dehnik (1973). Species names are given in accordance with the World Register of Marine Species (http://www.marinespecies.org at VLIZ. doi: 10.14284/170). The feeding of the fish larvae was studied using a fixed material by the method of Duka and Sinyukova (1976). A total of 40 samples collected at 21 stations, including one daily station, were analyzed.

The zooplankton samples were collected with a large Juday net (mouth area 0.1 m^2, mesh size 150 μm) simultaneously with ichthyoplankton samples. Taxonomic and quantitative processing of zooplankton samples was carried out by the fractional method in a stationary laboratory. Based on the results of two or more reads in a Bogorov chamber, the average abun-

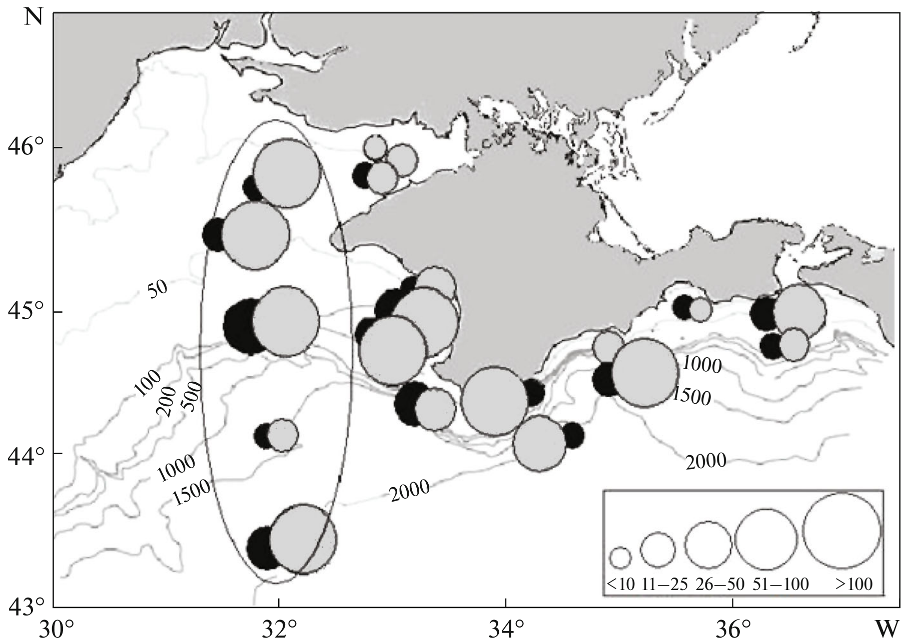

Fig. 1. Distribution of ichthyoplankton off the coast of the Crimean Peninsula in August 2011: (●) eggs, egg/m^2, (●) larvae, ind./m^2; (—) isobaths. The western polygon is highlighted by an oval.

dance of each species was calculated; for copepods, all stages of development were determined. Rare and large forms were counted for the whole sample. The organisms were measured with an eyepiece micrometer. The zooplankton biomass was calculated using the species abundance and the published values of their individual masses (Petipa, 1957).

RESULTS AND DISCUSSION

During the study period, along the Crimean coast from the Kerch Strait to the Karkinit Bay, 2103 eggs and 436 fish larvae belonging to 19 species from 16 families were caught. The average egg abundance was 111.0 egg/m^2 and larvae abundance was 22.4 ind./m^2. The average abundance of ichthyoplankton off the coast of Crimea in August 2011 was twice as high as in July 2010 (Klimova et al., 2014). European anchovy *Engraulis encrasicolus* dominated. The average abundance of its larvae in 2011 was comparable to that observed in July 1988, while the number of eggs was twice as high (Klimova, 2005). Despite the high ratio of dead eggs of European anchovy in the samples (76%), the relative abundance of larvae of this species averaged 17% of the egg abundance in the samples.

According to the abundance and species composition of the fish eggs and larvae, we have identified two zones: (1) the western polygon in the open sea: from the Tendrovskaya Spit along the western coast of Crimea to the western halistatic zone; (2) the shelf of the Crimean Peninsula from Karkinit Bay to Kerch Strait (Fig. 1). In the western polygon, the ichthyoplankton was mainly represented by the commercial migratory species. Here, an increased number of the fish eggs and larvae and a relatively small number of species were observed (Table 1). Average egg abundance was 147.9 egg/m^2 and larvae was 39.2 ind./m^2. The maximum number of eggs was recorded in Karkinit Bay (224 egg/trawling), while that of the larvae was observed in the western halistatic zone (depth 2038 m) at the daily station (70 ind./trawling). Eggs (99%) and larvae (83%) of European anchovy dominated, the share of the larvae of the Mediterranean horse mackerel *Trachurus mediterraneus* (16.8%) was comparatively high, and the other species were found occasionally. The abundance of eggs and larvae of European anchovy and Mediterranean horse mackerel were similar in the 25–0 and 100–0 m layers, while the eggs and larvae of cold-water species, European sprat *Sprattus sprattus* and whiting *Merlangius merlangus*, were found only in the 100–0-m layer.

Both commercial migratory species and local coastal species of the fish were found in ichthyoplankton on the shelf of the Crimean Peninsula (Table 1). Here, as in the western polygon, the eggs and larvae of the European anchovy prevailed. European anchovy was not found only at one shallow station (22 m) in Feodosia Gulf. At this station, the ichthyoplankton was represented by the eggs of the dragonet *Callionymus* sp. and the blackhand sole *Pegusa nasuta*. In Karkinit Bay, the egg abundance averaged 10 egg/m^2 and larvae averaged 0.7 ind./m^2. Only three fish species were identified in the ichthyoplankton (European anchovy, horse mackerel, and dragonet). All of them

Table 1. Species composition of the fish eggs and larvae in the shelf and open waters of the Crimean Peninsula in August 2011, % of the total abundance

Species	Western polygon	Shelf of Crimean Peninsula					
		Karkinit Bay	at Eupatoria	at Cape Khersones	at Yalta	Feodosia Gulf	Kerch pre-strait
Engraulis encrasicolus Linnaeus, 1758	99.1 / 82.9	93.0 / 0	99.4 / 85.0	97.2 / 88.9	95.7 / 81.0	94.0 / 73.2	86.6 / 78.0
Sprattus sprattus (Linnaeus, 1758)	0.1 / 0	–	–	–	0.9 / 0	2.3 / 0	2.8 / 0
Merlangius merlangus Linnaeus, 1758	0 / 0.3	–	–	–	–	0 / 6.7	5.3 / 0
Syngnathus schmidti Popov, 1927	–	–	0 / 3.9	0 / 3.7	0 / 3.8	–	–
Salaria pavo (Risso, 1810)	–	–	–	–	–	0 / 6.7	–
Parablennius tentacularis (Brünnich, 1768)	–	–	–	0 / 3.7	–	–	–
Callionymus sp.	–	7.0 / 0	–	–	–	1.5 / 0	–
Gobius niger Linnaeus, 175	–	–	–	–	0 / 3.8	0 / 6.7	–
Pomatoschistus marmoratus (Risso, 1810)	–	–	0 / 3.9	–	–	–	–
Liza saliens (Risso, 1810)	0.2 / 0	–	–	–	–	–	–
L. aurata (Risso, 1810)	0.3 / 0	–	–	–	–	–	–
Mugil cephalus Linnaeus, 1758	–	–	–	–	0.3 / 0	–	–
Trachurus mediterraneus (Steindachner, 1868)	0.3 / 16.8	0 / 100	0.3 / 7.2	2.8 / 3.7	1.2 / 0	1.5 / 6.7	02 / 2.0
Mullus barbatus Linnaeus, 1758	–	–	–	–	0.6 / 0	–	5.3 / 0
Pomatomus saltatrix (Linnaeus, 1766)	–	–	–	–	0.3 / 0	–	–
Sciaena umbra (Linnaeus, 1758)	–	–	–	–	0.3 / 0	–	–
Diplodus annularis (Linnaeus, 1758)	–	–	0.3 / 0	–	–	–	–
Trachinus draco Linnaeus, 1758	–	–	–	–	0.6 / 0	–	–
Pegusa nasuta (Pallas, 1814)	–	–	–	–	–	0.7 / 0	–
Mean abundance, egg/m^2/ind./m^2	147.9 / 39.2	10.0 / 0.7	242.7 / 18.0	36.0 / 27.0	96.4 / 8.0	66.5 / 7.5	24.6 / 5.9

Numbers above the line indicate eggs, and those below the line indicate larvae.

were caught in the southern part of the bay near Tarkhankut. In the northern part of the bay, where the thermocline layer located at a depth of 10 m, only one dead egg of anchovy was found. The greatest number of species was recorded near Yalta shore (10) and in the Feodosia Gulf (8). Here, as in other study areas, eggs and larvae of European anchovy dominated. In the vicinity of Yalta, there were sporadic findings of the eggs of the red mullet *Mullus barbatus*, the bluefish *Pomatomus saltatrix*, the brown meagre *Sciaena umbra*, and the greater weever *Trachinus draco*. The eggs and larvae of cold-water species, European sprat and whiting, were found at the depths above 90 m. The average egg abundance in the areas of Yalta and Feodosia was 96.4 and 66.6 egg/m^2, respectively; the average larvae abundance in both regions did not exceed 8 ind./m^2. In these areas, the proportion of larvae in the samples was the same (>8% of the egg abundance), despite the fact that the ratio of the dead eggs in the Feodosia region was larger by 25%. The maximum egg abundance (242.7 egg/m^2) was observed in Eupatoria, where the eggs and larvae of the five fish species were recorded. The eggs of the European anchovy dominated (99.4%), the eggs of the horse mackerel and of the annular seabream *Diplodus annularis* totaled 0.6%. Among the larvae (18 ind./m^2), European anchovy and horse mackerel prevailed; the Black-Sea pelagic pipefish *Syngnathus schmidti* and the marbled goby *Pomatoschistus marmoratus* were found in single specimens. The dead eggs of European anchovy contributed a little more than 93%, while the ratio of its larvae was 6.3% of egg number in the samples. The species number recorded in the Kerch prestrait was similar to that observed in vicinity of Eupatoria; however, the egg abundance was an order of magnitude lower (24.6 egg/m^2). The ratio of dead eggs of European anchovy did not exceed 40%. The ratio of larvae was 22% of the egg number in the samples and was comparable to the values obtained at the western polygon. At the station nearest to the Kerch Strait (depth 36 m), the number of eggs and larvae of the European anchovy was six times higher than over greater depths. At the shelf of the Crimean Peninsula, the maximum abundance of larvae (27 ind./m^2) was recorded at Cape Khersones over a depth of 152 m (Fig. 1), while the egg abundance here was low, 36 egg/m^2. The ratio of dead eggs was approximately 80%. Eggs (97.2%) and larvae (89%) of European anchovy dominated. Eggs and larvae of horse mackerel, Black-Sea pelagic pipefish, and tentacled blenny *Parablennius tentacularis* were sporadic. Over 70% of the anchovy eggs were at the V stage of development. The ratio of the larvae of this species exceeded 68% of the egg abundance in the sea.

The alternation of the stages of embryonic and postembryonic development in accordance with the rhythms of the anchovy reproduction (according to Dehnik, 1973) was examined for 644 eggs and 172 larvae collected at a daily station (43°210′ N 32°096′ E) in the western halistatic zone above the depth of 2038 m. The maximum number of eggs at the first and the second developmental stages were noted from midnight to 8 a.m. during the spawning period; 97.7% of the eggs were dead, alive eggs were recorded only at midnight. In our samples, the ratio of the eggs at I and II developmental stages was 54%; at III, IV, V, and VI stages, 6, 10, 24, and 6%, respectively. At the same time, the ratio of dead eggs at the III developmental stage was 68%; it decreased down to 29% for IV stage and to 5% for V stage. The dead fish eggs was not met at the VI stage of development. High mortality of the eggs of the stages I–III is a characteristic for the European anchovy inhabiting the Black Sea and the Sea of Azov (Dekhnik, 1979). The rate of the larvae of the endogenous (group 1), mixed (group 2), and external nutrition (group 3) averaged 2, 32, and 66%, respectively. At the same time, the larvae of all three size groups were caught only at 7 a.m. and at 7 p.m.; the larvae of the third size group were found in all the catches (Fig. 2).

The survival rates of the European anchovy at different stages of the embryonic and larval development (Table 2) were calculated using original and published data (Dekhnik, 1960); the latter were collected at the three daily stations 14 miles west of Cape Lukull at a depth of approximately 200 m in July–August 1957. The survival rates of the eggs and larvae at different stages of development were calculated in relation to the number of the eggs at the stages I–II, assuming that all of the eggs that were suspended (caught by the net) were alive (Dekhnik, 1960). The mortality rate for the life period from the final stages (V–VI) of embryonic development to the larvae of the first size group in 2011 was comparable to that in 1957 (98%). While, the survival rates of larvae in 2011 were higher than in 1957: 0.8 vs. 0.6% survived[1] before entering the endogenous nutrition stage, 18.1 vs. 2.2% to the stage of mixed nutrition, 29.7 vs. 0.2% to the stage of external nutrition. The ratio of different size groups of the anchovy larvae in August 2011 at all stations except daily station was comparable to that in July–August 1957. A high proportion of larvae of the third size group at the daily station may be associated with the peculiarities of the hydrological regime in this area. Anchovy larvae inhabit the 0–20-m layer (Duka, 1961) and are passively transported by the currents, keeping in zones with low dynamic activity of the water, characterized by a well-warmed upper quasi-homogeneous layer, where favorable conditions for their development are observed.

[1] In 1957 and 2011, the second size group of larvae exceeded the first group in number, which is explained by the error in the method of the net catches; when the plankton net is towed, the prelarvae lose the yolk sac and escape through the mesh (Dekhnik, 1960; Duka, 1961).

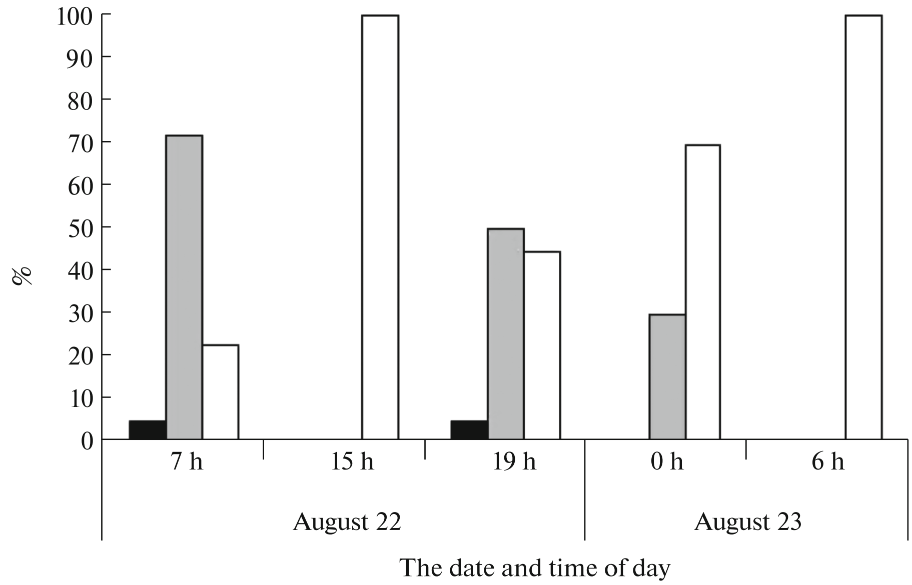

Fig. 2. Size composition of larvae of the European anchovy *Engraulis encrasicolus* sampled at the daily station (August 22–23, 2011). Size groups (according to: Duka, 1961): (■) first, 2.0–3.5 mm; (■) second, 3.6–6.0 mm; (□) third, 6.1–12.0 mm.

The feeding of the European anchovy was studied for 155 larvae collected at the daily station. In their guts were only food items which looked like undigested mass. Juvenile stages of copepods and cladocerans (1–3 specimens), as well as the eggs of hydrobionts, were identified only in the larvae that exceeded 4.8-mm long. According to the literature (Duka, 1961; Dehnik, 1973), the anchovy larvae of a 2.0–3.5-mm length are characterized by the feeding on the yolk sac; during the second day, the yolk sac is almost completely resorbed in the larvae, and they switch to the mixed nutrition; phytoplankton, eggs, and copepods of juvenile stages are found in their gut content.

In all the study areas, the species composition of the food objects of fish larvae of the families Engraulidae, Carangidae, Blenniidae, and Gobiidae practically did not differ and by juvenial stages of copepods and cladocerans. The average body length of consumed copepods varied within the range 0.12–0.30 mm, while the cladocerans were within 0.25–0.40 mm.

In August 2011, the species composition of the zooplankton corresponded to the summer season, characterized by a high number of warm-water species of copepods and cladocerans, and high abundance of their juveniles and of the larvae of benthic animals. A total of 35 taxa were found. The total abundance of

Table 2. Elimination ratio of European anchovy *Engraulis encrasicolus* at different stages of embryonic-larval development in 1957 (Dekhnik, 1960) and 2011 (original data), mean values are presented for the daily stations

Stage of egg development and size group of larvae	Cape Lukull, July–August 1957			Western halistatic zone, August 2011		
	abundance		mortality rate, %**	abundance		mortality rate, %**
	ind.	ratio, %*		ind.	ratio, %*	
Eggs						
I–II	187.3	100		353	100	
III–IV	132.0	70.5	29.5	102	28.9	71.1
V–VI	63.3	33.8	52.0	189	53.5	
Larvae, mm						
1 – 2.0–3.5	1.1	0.6	98.3	3	0.8	98.2
2 – 3.6–6.0	4.2	2.2		64	18.1	
3 – 6.1–12.0	0.4	0.2		105	29.7	

* Relative to the number of eggs at I–II stages of development. ** Relative to the previous stage.

the fodder zooplankton in the whole water column varied within 489–25200 ind./m^3, and biomass was within 23.6–491.7 mg/m^3. In 2011, the microzooplankton abundance was comparable to that observed in the 1980s before the invading of the ctenophore *Mnemiopsis* (Seregin and Popova, 2015). Small crustaceans—copepods and cladocerans—dominated in the fodder zooplankton at all the stations; copepods constituted approximately 60% of the population and 56% of the biomass on average, while cladocerans 15 and 24%, respectively. In the Karkinit Bay, where the maximum abundance of microzooplankton was registered (up to 300000 ind./m^3), the larvae of bivalve mollusks predominated (Seregin and Popova, 2015). *Oithona davisae*, the recent alien cyclopoid copepod in the Black Sea, dominated by the abundance (21.7%) in fodder zooplankton. The eggs and the nauplii of copepods constituted 16.8%, the copepod *Acartia clausi* constituted 15.6%, the larvae of bivalve mollusks constituted 13.2%, the cladoceran *Penilia avirostris* constituted 2.9%, and the larvae of barnacles constituted 2.2%. Other species of copepods (*Oithona similis, Pseudocalanus elongatus,* and *Paracalanus parvus*) and representatives of the other groups (*Oikopleura dioica*, pelagic larvae of polychaetes and gastropods) each constituted less than 1.5–2.0% of the total abundance of the fodder zooplankton.

The spatial distribution of planktonic organisms largely depends on the hydrological conditions. In the second decade of August 2011, the northeasterly trade winds prevailed over the shelf of the Crimean Peninsula, reaching 16 m/s. This led to the dispersal of surface water into the open sea and to a decrease of the water temperature near the coast. On the shelf off the western and the southwestern coasts of the Crimean Peninsula and in the Feodosia Gulf, the temperature of the surface water layer decreased down to 20–22°C and down to 19°C in the Karkinit Bay, while it exceeded 25°C in July 2011 (Klimova et al., 2012). Planktonic organisms, including fish eggs and larvae, were transported with the surface waters from the shelf to the open sea. For example, at the coastal stations in the Karkinit Bay, the maximum abundance of the fish eggs did not exceed 12 egg/m^2, and the fish larvae were found only at one station, while at the entrance of the bay, far to the sea, the egg abundance exceeded 400 egg/m^2, and the larvae abundance exceeded 20 ind./m^2 (Fig. 1). A similar pattern was observed near Eupatoria shore: the abundances of eggs and larvae in the coastal station were 40 egg/m^2 and 8 ind./m^2, respectively, and reached 370 egg/m^2 and 80 ind./m^2 at the deep-water stations. The jelly macroplankton was distributed similarly, and was represented by the three species of ctenophores (*B. ovata, M. leidyi*, and *Pleurobrachia pileus*) and jellyfish *Aurelia aurita* (Klimova et al, 2012).

Currently, the development of the *M. leidyi* population during the summer months is controlled by the ctenophore *B. ovata*, which actively consumes *Mnemiopsis*, reducing its numbers. As a result, the *Mnemiopsis* press on the zooplankton decreases, and, thus, the zooplankton abundance in summer does not decrease as dramatically as it did in the 1990s. In 2010 and 2011, the abundance of the fodder zooplankton at the shelf of the Crimean Peninsula and in the coastal area near Sevastopol remained relatively high because a brief, lasting for not more than 2 weeks, outbreak of *M. leidyi* abundance that occurred before the appearance of *B. ovata*; it did not reduce the zooplankton abundance to catastrophically low values, so the late-summer depression of zooplankton was not observed as it was noted in the 1990s (Gordina et al., 2005; Abolmasova et al., 2012; Shiganova et al., 2014; Finenko and Datsyk, 2016).

CONCLUSIONS

(1) In August 2011, along the coast of the Crimean Peninsula, fish eggs and larvae representing 19 species from 16 families have been found. The average abundance of eggs (111.0 egg/m^2) and larvae (22.4 ind./m^2) was twice as high as that registered in July 2010. The European anchovy dominated in the ichthyoplankton: the larvae abundance was comparable to that in July 1988, and the egg abundance was twice as high.

(2) In August 2011, the mortality rate of European anchovy during the life cycle period from the V–VI stages of egg development to the larvae at the stage of endogenous nutrition was similar to that observed in July–August 1957, constituting 98%. The high abundance of larvae of the older age group, recorded in the western halistatic zone, was preconditioned by the peculiarities of the hydrological regime that facilitated their passive transport from the adjacent areas.

(3) In the studied water area, the species composition of the food objects in the gut of fish larvae of the families Engraulidae, Carangidae, Blenniidae, and Gobiidae practically did not differ; copepods and the cladocerans of juvenile stages were the basis of their food supply.

(4) The decrease in the press of predatory *Mnemiopsis* led to an increase in the abundance of the fodder zooplankton in the sea, in particular, of the copepods of the naupliar and copepodite stages, whose ratio increased up to 80%.

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