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Species Composition and Seasonal Dynamics of Ichthyoplankton of the Coastal Zone of the Western Part of Peter the Great Bay of the Sea of Japan in 2007–2010

I. V. Epur and A. A. Balanov

Institute of Marine Biology, Far Eastern Branch, Russian Academy of Sciences, ul. Palchevskogo 17, Vladivostok, 690041 Russia

e-mail: iraepur@mail.ru

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Abstract—Data on species composition of ichthyoplankton of the coastal zone of western part of Peter the Great Bay of the Sea of Japan are generalized. Here eggs, larvae, and fry of 77 species of fish belonging to 25 families occur, which comprises 24.4% of the total number of species inhabiting Peter the Great Bay. Among the studied water areas, maximum species diversity (60 species) was recorded in ichthyoplankton of the eastern site of the sea biosphere reserve. Seasonal dynamics of species composition of ichthyoplankton of the coastal zone of the western part of Peter the Great Bay was traced: number of species reduced from 52 in May to two in October.

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Keywords: ichthyoplankton, seasonal dynamics, western part of Peter the Great Bay, Sea of Japan

INTRODUCTION

At the present time, one of the most urgent ecological tasks is the study and preservation of biological diversity on our planet. To solve this problem, regional and global programs, such as "Diversitas in Western Pacific and Asia" (DIWPA) and "Census of Marine Life" (CoML) have been elaborated in recent years, whose purpose is assessment of marine biological diversity and study of specific features of distribution and abundance of hydrobionts in the World Ocean (Adrianov, 2004). In the framework of long-term projects on the study of biological diversity of the western and northern Pacific, Peter the Great Bay of the Sea of Japan was selected as a control water area on monitoring of coastal diversity.

In a complex of observations of the state of ichthyofauna, ichthyoplankton studies assume ever greater importance, especially when they are performed throughout a rather long period. The data of the study make it possible to specify evidence on the ichthyofauna of the area, since some species of fish in an adult state lead a secretive mode of life and are not caught by usual fishing gear, and their presence in the given water area is fixed only by results of ichthyoplankton collections (Sokolovsky and Sokolovskaya, 1996; Sokolovskaya et al., 2010). The study of ichthyoplankton also allows estimation of the efficiency of reproduction of many fish species (both of traditional objects of fishery and noncommercial species playing an important role in coastal diversity) and subsequent tracing variation in their numbers.

Ichthyoplankton studies were successfully performed mainly in the open part of Peter the Great Bay (Gorbunova, 1954; Kaganovskaya, 1954; Pertseva-Ostroumova, 1955, 1961; Rass et al., 1962) and, to a smaller degree, in covered areas of coastal shallow waters of its western part (Davydova, 1994; Epur et al., 2008; Kos'yanenko et al., 2013). Since 1998, studies have been performed in the southern part of Far Eastern Marine Biosphere State Nature Reserve, Far Eastern Branch, Russian Academy of Sciences (DVMBGPZ DVO RAN) located in the western part of Peter the Great Bay (Sokolovsky and Sokolovskaya, 1999, 2000; Sokolovskaya and Epur, 2001; Epur, 2002, 2008). In 2007, regular works on inventorying and monitoring of the eastern part of this reserve were started (Epur and Balanov, 2009, 2011; Balanov et al., 2010; Balanov and Epur, 2011).

The purpose of our investigations was to study species composition and seasonal dynamics of ichthyoplankton of the coastal zone of the western part of Peter the Great Bay.

MATERIALS AND METHODS

Ichthyoplankton samples were collected in May–October 2007–2010 in the water area of the eastern site of the marine reserve during joint scientific-research-works of the Institute of Marine Biology (Far East Branch, Russian Academy of Sciences) and DVMBGPZ DVO RAN. In each of the studied seasons, ichthyoplankton samples were collected accord-

Table 1. Number of ichthyoplankton samples taken in the water area of the eastern site of the marine reserve (DBMBGPZ DVO RAN) in May–October 2007–2010

Year	Month						Total
	may	june	july	august	septemder	october	
2007	–	–	26	–	–	–	26
2008	26	–	23	–	24	–	73
2009	23	22	25	13	–	11	94
2010	–	–	24	24	14	22	84
Total	49	22	98	37	38	33	277

ing to one scheme at 22 stations located from Cape Lva to Cape Spaseniya (Epur and Balanov, 2011).

Ichthyoplankton was caught from the board of a boat using an IKS-80 egg net prepared in correspondence with recommendations of Rass and Kazanova (1966): the area of input opening 0.5 m^2 and net bag from capron gas no. 14 mm. Ichthyoplankton was collected in the surface horizon of water, at vessel circulation with a speed of 2.5–3.0 knots, with the net in a semi-immersed state (Sokolovskaya and Belyaev, 1987). Duration of one fishing was 10 min. Larvae and fry of fish were collected also at light stations from 10:00 p.m. to 1:00 a.m. The source of light was a lamp of day light (power of 500 W) that was suspended at a distance of 0.5–0.7 m from the sea surface. At the site of performing light stations, sea depth was 3–4 m. Fish attracted to the illuminated zone were fished by fine-mesh landing nets after 1 h following turning on of light (Sokolovsky and Sokolovskaya, 2008; Balanov et al., 2010). During sampling, water temperature on the surface was measured. A total of 277 samples of ichthyoplankton were collected and processed, in which more than 50000 individuals of eggs, larvae, and fry of fish were found. Of 277 samples, 21 were taken at light stations, and the remaining 256 samples were with the IKS-80 (Table 1).

The material obtained was fixed by 4% solution of formalin for subsequent chamber treatment under laboratory conditions. In each sample, species composition of eggs, larvae, and fry of fish and their sizes and amount were determined. During identification of eggs, the following characters were taken into account: shape, pattern and state of the envelope and its structure, state and structure of the yolk, presence of oil globule, and other specific features of pelagic eggs (Pertseva-Ostroumova, 1961; *An Atlas*..., 1988; Sokolovsky and Sokolovskaya, 2008). When measuring larvae and fry, recommendations of Ahlstrom et al. (1976) and Matarese et al. (1989) were followed. Total length (*TL*) of larvae and fry were measured with an accuracy to 0.1 mm using an Olympus microscope.

In total lists, taxa are arranged according to the classification of Nelson (2006), their systematic position corresponds to data published on the site *Catalogue of Fishes* (2013).

RESULTS AND DISCUSSION

In ichthyoplankton of the eastern site of the marine reserve in May–October 2007–2010, 60 species of fish belonging to 24 families were found (Table 2). This comprises 19.0% of the total number of species inhabiting Peter the Great Bay (Sokolovsky et al., 2011). Maximum number of taxa includes Acorpaeniformes (seven families and 27 species) and Perciformes (9 and 20, respectively). Representatives of these two orders form the basis of ichthyoplankton of the eastern site of the marine reserve, they account for 66.7% of families and 78.3% of species. Order Pleuronectiformes is also represented rather multivarietly (seven species). In the remaining five orders, the number of found species was small.

Maximum species diversity was found in families Cottidae: (nine species), Stichaeidae (nine), Pleuronectidae (seven), Agonidae (five), Gobiidae (four), Sebastidae (four), and Hexagramidae (four); the remaining 17 families are represented by one to three species of fish. One should also distinguish families represented by mass species of fish—Engraulidae (56.0% of the total number of caught individuals during the study period), Cottidae (22.0%), Gadidae (6.0%), and Stichaeidae (4.0%).

According to data of Davydova (1994), in ichthyoplankton of another site of the western part of Peter the Great Bay (Severnaya Inlet of Slavyanskii Bay) in April–June 1984–1986, 23 species of fish belonging to 14 families occur. Taking into consideration changes in the nomenclature of individual species of fish and excluding them from the list of representatives of nekton, such as *Oncorhynchus masou* and *Gasterosteus aculeatus*, we established that the following seven species were not recorded previously in the ichthyoplankton of the marine reserve: *Clupea pallasi*, *Salangichthys microdon*, *Stichaeus* sp., *Opisthocentrus zonope*, *Argyrocottus zanderi*, *Pseudopleuronectes yokohamae*, and *Lepidopsetta mochigarei*.

According to data of studies in March–November 2006–2007 and in May, August, and October 2010–2012, 39 species of fish belonging to 16 families were found in ichthyoplankton of Posyet Bay (Epur et al., 2008; Kos'yanenko et al., 2013). Of them, 27 species

Table 2. Composition of ichthyoplankton of the eastern site of the marine reserve (DVMBGPZ DVO RAN) in May–October 2007–2010

Species	Month and year												
	V		VI	VII				VIII		IX			X
	2008	2009	2009	2007	2008	2009	2010	2009	2010	2008	2009	2010	2010
Eggs													
Sardinops melanostictus	–	–	4.5/1	13.6/1	–	–	11.1/1	–	–	–	–	–	–
Engraulis japonicus	–	–	18.2/1	95.5/9	47.8/19	71.0/10	69.6/14	100/17	–	–	–	–	–
Cololabis saira	–	–	–	–	47.8/81	4.2/1	47.8/16	–	–	–	–	–	–
Hyporhamphus sajori	–	–	–	–	8.7/15	–	–	–	–	–	–	–	–
Liza haematochila	–	–	–	–	–	–	13.0/1	–	–	–	–	–	–
Limanda aspera	–	–	–	22.7/112	–	–	43.5/17	–	–	–	–	–	–
L. punctatissima	–	–	95.5/138	–	56.6/18	95.5/45	8.7/2	18.2/1	3.7/1	–	–	–	–
Pseudopleuronectes herzensteini	–	–	–	95.5/16	–	–	73.9/23	–	–	–	–	–	–
Glyptocephalus stelleri	–	–	59.1/6	–	–	–	13.4/2	–	–	–	–	–	–
Larvae and fry													
Konosirus punctatus	–	–	–	–	21.7/3	–	–	–	–	–	–	–	–
Sardinops melanostictus	–	–	–	–	4.3/1	–	34.8/1	–	–	–	–	–	–
Engraulis japonicus	–	–	–	100/86	39.1/16	33.3/1	47.8/66	100/2246	51.9/8	–	–	–	–
Hypomesus japonicus	–	4.3/1	–	–	–	–	–	–	–	–	–	–	–
Eleginus gracilis	89.2/114	87.0/18	9.1/3	–	–	–	–	–	–	–	–	–	–
Theragra chalcogramma	–	4.3/4	–	–	–	–	–	–	–	–	–	–	–
Cololabis saira	–	–	–	–	13.0/1	8.3/1	–	–	–	–	–	–	–
Hyporhamphus sajori	–	–	–	–	30.4/3	4.2/1	4.3/1	–	–	–	–	–	–
Syngnathus schlegelii	–	–	–	18.2/1	26.1/8	8.3/1	30.4/1	54.5/4	29.6/2	–	–	–	–
Sebastes sp.	–	–	–	–	26.1/8	–	4.3/1	–	3.7/1	–	–	–	–

Table 2. (Contd.)

Species	Month and year												
	V		VI	VII				VIII		IX			X
	2008	2009	2009	2007	2008	2009	2010	2009	2010	2008	2009	2010	2010
S. owstoni	–	–	–	–	21.7/2	–	–	–	–	–	–	–	–
S. schlegelii	–	–	27.3/1	–	30.4/2	–	4.3/1	–	3.7/1	–	–	–	–
S. taczanowskii	–	–	9.1/1	–	17.4/1	4.2/1	34.8/4	–	3.7/1	–	–	–	–
Hexagrammos stelleri	–	–	–	–	–	–	–	–	–	9.1/6	–	–	–
H. octogrammus	10.7/1	–	–	–	–	–	–	–	–	–	20.0/4	–	20.0/4
Pleurogrammus azonus	–	–	–	–	–	–	–	–	–	–	–	–	9.5/1
Bero elegans	10.7/1	–	–	–	–	–	–	–	–	–	–	–	–
Enophrys diceraus	17.9/28	13.0/1	–	–	–	–	–	–	–	–	–	–	–
Gymnocanthus cf. *intermedius*	42.9/8	39.1/21	–	–	–	–	–	–	–	–	–	–	–
Myoxocephalus brandtii	32.1/171	74.0/179	–	–	–	–	–	–	–	–	–	–	–
M. jaok	81.8/247	34.8/9	–	–	–	–	–	–	–	–	–	–	–
M. stelleri	14.3/24	47.8/14	–	–	–	–	–	–	–	–	–	–	–
Hemilepidotus gilberti	–	4.5/1	–	–	–	–	–	–	–	–	–	–	–
Porocottus allisi	7.1/6	4.3/7	–	–	–	–	–	–	–	–	–	–	–
Radulinopsis derjavini	3.6/1	–	–	–	–	–	–	–	–	–	–	–	–
Blepsias cirrhosus	7.1/1	4.3/1	–	–	–	–	–	–	–	–	–	–	–
B. bilobus	–	4.3/1	–	–	–	–	–	–	–	–	–	–	–
Nautichthys pribilovius	3.6/1	4.3/1	–	–	–	–	–	–	–	–	–	–	–
Dasycottus setiger	3.6/3	–	–	–	–	–	–	–	–	–	–	–	–
Agonomalus proboscidalis	10.7/2	–	–	–	–	–	–	–	–	–	–	–	–

Table 2. (Contd.)

Species	Month and year												
	V		VI	VII				VIII		IX			X
	2008	2009	2009	2007	2008	2009	2010	2009	2010	2008	2009	2010	2010
Pallasina barbata	7.1/3	–	–	–	–	–	–	–	–	–	–	–	–
Podothecus sachi	7.1/5	17.4/1	–	–	–	–	–	–	–	–	–	–	–
P. sturioides	32.1/3	47.8/4	–	–	–	–	–	–	–	–	–	–	–
Tilesina gibbosa	17.9/3	17.4/2	–	–	–	–	–	–	–	–	–	–	–
Aptocyclus ventricosus	–	8.7/1	–	–	–	–	–	–	–	–	–	–	–
Liparis agassizii	3.6/1	47.8/3	–	–	–	–	–	–	–	–	–	–	–
Liza haematochila	–	–	–	18.2/2	–	–	17.4/1	–	–	–	–	–	–
Neozoarces steindachneri	3.6/1	–	–	–	–	–	–	–	–	–	–	–	–
Chirolophis japonicus	–	21.7/1	–	–	–	–	–	–	–	–	–	–	–
Ch. saitone	3.6/3	–	–	–	–	–	–	–	–	–	–	–	–
Acantholumpenus mackayi	3.6/1	–	–	–	–	–	–	–	–	–	–	–	–
Lumpenus sagitta	14.2/15	60.9/64	–	–	–	–	–	–	–	–	–	–	–
Opisthocentrus ocellatus	17.9/96	4.3/56	–	–	–	–	–	–	–	–	–	–	–
O. tenuis	–	4.3/3	–	–	–	–	–	–	–	–	–	–	–
Pholidapus dybowskii	–	8.7/1	–	–	–	–	–	–	–	–	–	–	–
Stichaeus grigorievi	–	4.3/3	–	–	–	–	–	–	–	–	–	–	–
Cryptacanthoides bergi	14.2/4	47.8/2	–	–	–	–	–	–	–	–	–	–	–
Rhodymenichthys dolychogaster	3.6/1	26.1/6	9.1/1	–	–	–	–	–	–	–	–	–	–
Pholis crassispina	–	39.1/8	–	–	–	–	–	–	–	–	–	–	–
Arctoscopus japonicus	17.9/2	4.3/2	–	–	–	–	–	–	–	–	–	–	–

Table 2. (Contd.)

Species	Month and year												
	V		VI	VII				VIII		IX			X
	2008	2009	2009	2007	2008	2009	2010	2009	2010	2008	2009	2010	2010
Eleutherochir mirabilis	–	–	–	–	–	–	–	–	3.7/1	–	–	–	–
Gymnogobius heptacanthus	–	–	–	–	34.5/2	12.5/19	4.3/1	–	3.7/2	–	–	–	–
Luciogobius guttatus	–	–	–	–	4.3/1	–	–	–	–	–	–	–	–
Pleuronectidae gen. sp.	–	–	9.1/1	–	–	–	8.7/2	–	–	–	–	–	–
Limanda aspera	–	–	–	–	–	8.3/1	–	–	3.7/2	–	–	–	–
Liopsetta pinnifasciata	–	4.3/1	–	–	–	–	–	–	–	–	–	–	–
Platichthys stellatus	–	–	13.6/1	–	–	–	–	–	–	–	–	–	–
Pseudopleuronectes herzensteini	–	–	27.3/2	–	–	–	–	–	–	–	–	–	–
Glyptocephalus stelleri	–	–	–	–	–	4.2/1	–	–	–	–	–	–	–
Total species	27	29	11	6	13	9	15	3	9	1	1	–	2

Above the line—frequency of occurrence in catches, %; under the line—average number, ind./catch.

of fish are common with species of ichthyoplankton of the eastern site of the marine reserve, two species (*C. pallasi* and *Ps. yokohamae*) with ichthyoplankton species of Severnaya Inlet, and the remaining 10 species (*Hippocampus japonicus*, Cottidae gen. sp., *Gymnocanthus* sp., *Hypsagomus corniger*, *Liparis* sp., *Stichaeidae* gen. sp., *Stichaeus nozowae*, *Acentrogobius pflaumi*, *Hippoglossoidus dubius*, and *P. obscurus*) are found only in Posyet Bay.

Thus, using published data and results of our own studies, we found that there are 77 species of fish belonging to 25 families or 24.4% of the total number of fish inhabiting this bay in ichthyoplankton of the coastal zone of the western part of Peter the Great Bay (Davydova, 1994; Epur et al., 2008; Kos'yanenko et al., 2013). Maximum species diversity was recorded in ichthyoplankton of the eastern site of the marine reserve—60 species of fish. It is likely that such diversity is explained by the fact that our studies were performed during a rather prolonged period (2007–2010) and embraced three seasons (spring, summer, autumn).

In waters of the marine reserve, the highest number of species in ichthyoplankton community was recorded in May—38 species of fish belonging to 15 families. Among them most common and mass were species such as *Eleginus gracilis*, *Myoxocephalus jaok*, *M. brandtii*, and *Lumpenus sagitta* (Table 2).

Spawning of *E. gracilis* in Peter the Great Bay begins in December before the formation of an ice fringe in shallow-water inlets and bays and continues up to the middle of February (Nuzhdin, 1994). Hatching of larvae occurs at the end of April or May not long before beginning of warming of coastal waters (Sokolovskii and Sokolovskaya, 2008). Their aggregations are observed not far from the spawning grounds, but are slightly displaced to larger depths—up to 15–25 m (Nuzhdin, 1994). As a rule, larvae and fry of *E. gracilis* settle under domes of jellyfish *Cyanea capillata* and are dispersed by currents in different directions (Vdovin et al., 1997). According to data of our visual observations, aggregations of jellyfish *C. capillata* were recorded in May on the studied water area, under whose domes (with diameter of 5–30 cm) fry of *E. gracilis* were recorded. In spring 2008 and 2009, the frequency of occurrence of fry of *E. gracilis* in catches was relatively the same and comprised 89.2 and 87.0%,

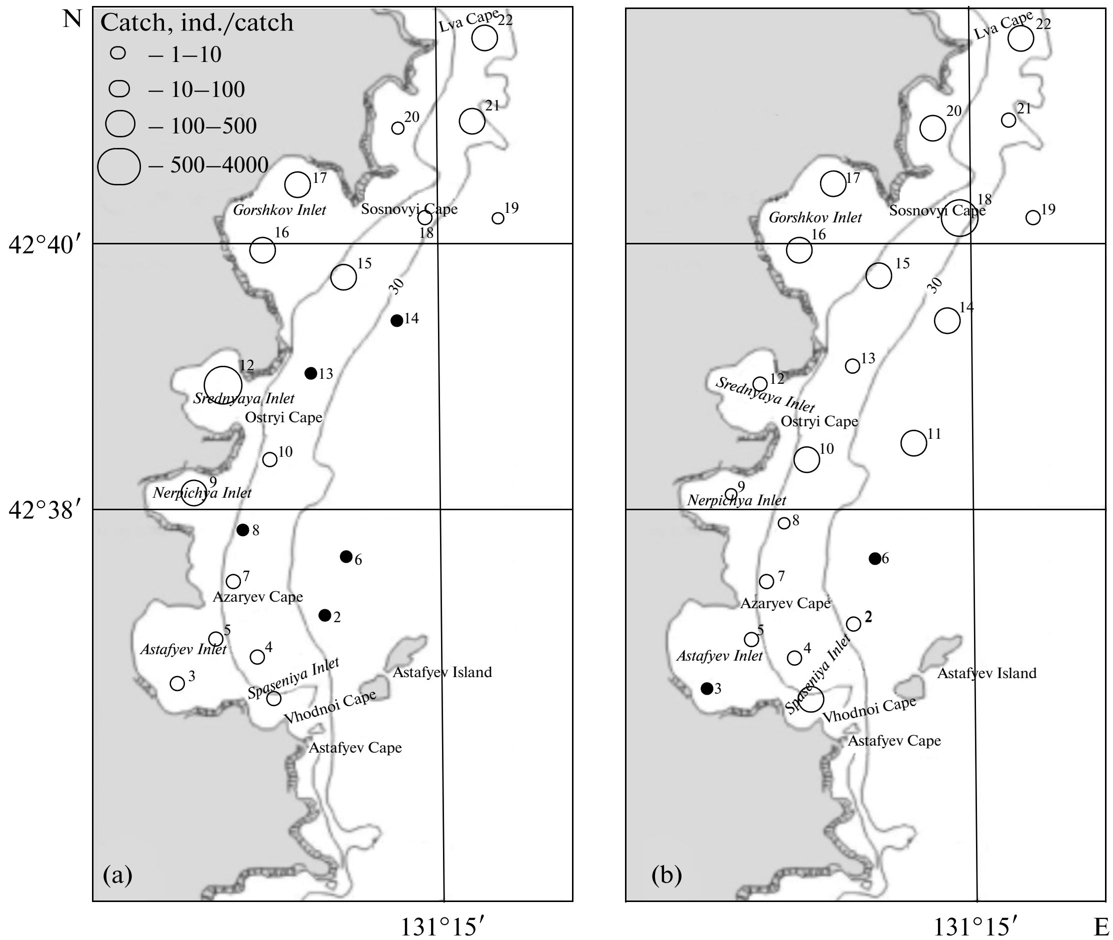

Fig. 1. Distribution of larvae and fry of representatives of the genus *Myoxocephalus* over the water area of the eastern site of the marine reserve (DVMBGPZ DVO RAN) in May: (a) 2008, (b) 2009; 1–22—numbers of sampling stations; (—) isobaths.

respectively. During this period, 2928 individuals *TL* 8.0–21.0 mm were caught.

In May, representatives of the genus *Myoxocephalus* (Cottidae) were constantly found in ichthyoplankton samples and were among the most numerous components of ichthyoplankton community of surface waters. In 2008, the frequency of occurrence in catches of *M. jaok* was 81.8% with maximum numbers of it in catch (2182 individuals) (May 10, 2008). In 2009, another species—*M. brandtii*—dominated in catches, with frequency of occurrence 74.0% and maximum numbers in catch (2983 individuals) (May 21, 2009). In this year, it was most mass and its frequency of occurrence was by 41.9% greater than in the preceding year (Table 2). In May 2008–2009, distribution of larvae and fry of *M. brandtii* and *M. jaok* at sites of their aggregations was not uniform; their numbers at 22 stations differed considerably. Maximum concentration of larvae and fry of the given species was observed, as a rule, at coastal stations with depths up to 30 m (Fig. 1). Pelagic juveniles of *M. stelleri* at this time were rare; frequency of their occurrence in catches in 2008 was 14.3% and that in 2009 was 47.8% (Table 2).

All the listed by us species of the genus *Myoxocephalus* are common for the eastern site of the marine reserve and have high numbers not only at the studied site but also in Peter the Great Bay (Sokolovsky and Sokolovskaya, 1997; Panchenko, 2001a, 2001b, 2001c). Frequency of occurrence and quantitative indices between species vary from year to year; this possibly occurs because of natural fluctuations in their numbers.

Among representatives of the family Agonidae, most numerous in May were *Podothecus sturiodes* and *Tilesina gibbosa*. Evidence on biology of *P. sturiodes* is very scarce. Its spawning presumably takes place in spring (Maeda and Amaoka, 1988). According to data of Sokolovsky and Sokolovskaya (2008), larvae *TL* approximately 10.0 mm were found in May in catches of plankton nets. The length of our individuals (*TL* 12.5–22.0 mm) considerably exceeded sizes indicated by these authors. In the course of studies, more than 100 larvae of *P. sturiodes* were caught; frequency of occurrence in 2008 was 32.1% and that in 2009 was 47.8%. Their maximum concentration (34 ind./catch) was recorded at station no. 17 (May 21, 2009). Larvae

Table 3. Change in qualitative and quantitative composition of ichthyoplankton collected by net IKS-80 in May 2009 in the water area of the eastern site of the marine reserve (DVMBGPZ DVO RAN)

Species	Number of larvae in a sample, ind.	
	20–22.05.2009	24.05.2009
Hypomesus japonicus	1 (0–6)	–
Eleginus gracilis	27 (0–108)	9 (0–26)
Theragra chalcogramma	1 (0–4)	–
Enophrys diceraus	1 (0–8)	–
Gymnocanthus cf. *intermedius*	34 (0–252)	7 (0–58)
Myoxocephalus brandtii	335 (25–2983)	23 (0–110)
M. jaok	14 (0–54)	3 (0–27)
M. stelleri	23 (0–87)	5 (0–23)
Hemilepidotus gilberti	1 (0–1)	–
Blepsias cirrhosus	1 (0–1)	–
B. bilobus	1 (0–1)	–
Podothecus sachi	1 (0–10)	1 (0–2)
P. sturioides	6 (0–34)	1 (0–6)
Tilesina gibbosa	1 (0–2)	2 (0–12)
Aptocyclus ventricosus	1 (0–4)	–
Liparis agassizii	4 (0–22)	1 (0–6)
Chirolophis japonicus	1 (0–6)	–
Lumpenus sagitta	103 (0–418)	24 (0–170)
Pholidapus dybowskii	–	1 (0–4)
Rhodymenichthys dolychogaster	8 (0–56)	3 (0–28)
Cryptacanthoides bergi	2 (0–8)	1 (0–6)
Pholis crasispina	14 (0–142)	1 (0–8)
Arctoscopus japonicus	2 (0–30)	–
Liopsetta pinnifasciata	1 (0–16)	–
Total species	23	14
Total samples	13	10

Beyond the parentheses—average value; in parentheses—limits of index variation.

of *T. gibbosa* were found considerably less frequently: frequency of occurrence in 2008 and 2009 was 17.9 and 17.4%, respectively. According to an oral communication of Sokolovskaya, larvae of *T. gibbosa* in Peter the Great Bay in 2005–2006 was recorded in catches of plankton nets in April, and their average length (*TL*) was 16.6 mm. Larvae of this species in our collections had average *TL* 23.5 mm. Over the studied water area, catches of *Agonomalus proboscidalis* were recorded. A total of seven larvae *TL* 10.0–11.0 mm were caught at stations nos. 9, 12, 14, and 17.

Species, such as *Porocottus allisi*, *Nautichthys pribilovius* (Epur and Balanov, 2000), *Stichaeus grigorievi*, *Opisthocentrus ocellatus*, and *O. tenuis* were found in May samples taken only at light stations.

We would like to call attention to the following historical fact. In May 2009, samples collected by net IKS-80 at different dates (May 20–22 and 24) considerably differed (Table 3). For instance, on May 20–22, 23 species of fish were present in the samples, while there were only 14 on May 24. The numbers of most mass species decreased multifold, in particular, of *M. brandtii* (from 335 to 25 ind./catch) and of *L. sagitta* (from 103 to 24 ind./catch). It can be assumed that we managed to catch the moment of sedimentation of larvae from plankton on the bottom. This supposition is supported by divers' observations performed in this period: if fry of representatives of the genus *Myoxocephalus* occurred singly on the bottom on May 20–22, they were recorded in mass on May 24. Note that average, minimal, and maximum temperature values of the surface water layer in the period between dates of sampling—May 20–22 and 24—considerably increased: from 8.0 (7.4–8.8) to 10.3 (9.0–11.2)°C. Thus, surface water temperature for 3 days rose by almost 2.5°C, which possibly stimulated the start of mass sedimentation of juveniles. It was previously supposed that termination of the pelagic stage of development of larvae of representatives of families, such as Cottidae, Stichaidae, Agonidae, etc., and, correspondingly, the onset of their sedimentation from surface warmed waters on the bottom occur at the end of May. In June, larvae of these families in ichthyoplankton collections are absent (Sokolovsky and Sokolovskaya, 1997, 2001; Davydova, 1998).

In summer months, numerous components of the ichthyoplankton community of the eastern site of the marine reserve were either migrants (*Konosirus punctatus*, *Engraulis japonicus*, *Hyporhamphus sajiori*, *Sardinops melanostictus*) or resident species (representatives of the families Pleuronectidae, Gobiidae, etc.), whose early stages of development occur in the summer period in the pelagial. In June–August in catches, there were no representatives of families numerous in species respect, such as Cottidae, Agonidae, Stichaeidae, and Hemitripteridae, that in spring formed the basis of ichthyoplankton. In June, July, and August, 11, 18, and 9 (6) species of fish (from six families) were recorded here, respectively (Table 2).

In the summer period, most numerous were larvae and fry of Sebastidae that dominated in catches of ichthyoplankton. Species of this family spawn from 10000 to 700000 prolarvae in May–June at water temperature not lower than 10°C (Sokolovsky et al., 2011). Larvae and fry of the family Sebastidae are common among drifting algae. In June–July 2008–2009, more than 250 larvae and fry of fish of this family were caught, among which *Sebastes schlegeli* and *N. taczanowskii* were most mass.

Two species of flounders—*Limanda punctatissima* and *Glyptocephalus stelleri*—were represented in catches mainly only by eggs that were at stage II–III of development (Table 2). Eggs of *L. punctatissima* with diameter of 0.76–0.78 mm were found from June to August. In June and July 2009, frequency of occurrence of eggs of *L. punctatissima* in catches reached 95.5%; its numbers averaged 138 and 45 ind./catch, respectively. This species is common in waters of the marine reserve (Markevich et al., 2004; Balanov et al. 2010; Epur and Balanov, 2011), as well as in Peter the Great Bay, northern Primorye, Tatar Strait, Bay Aniva, and off the Kuril Islands, where it comprises a noticeable proportion of biomass of flounders (Moiseev, 1946, 1953; Mikulich, 1954; Borets, 1990; Kolpakov, 2005). Eggs of *G. stelleri* (with diameter of 1.29–1.40 mm) occurred considerably more seldom: 59.1% in June and 13.4% in July; its catches averaged 2–6 ind./catch. This can be explained by the fact that mass spawning of this flounder takes place in Ussuri Bay, where it migrates from wintering sites from Peter the Great Bay (Moiseev, 1946; Pertseva-Ostroumova, 1961; Epur, 2009).

In summer months in ichthyoplankton of the studied water area, southern migrant *K. punctatus* occurred. Spawning of this species in Peter the Great Bay begins usually at the end of June–the first ten-day period of July, when coastal waters warm to 17–19°C and takes place over depths of 20–100 m (Sokolovsky and Sokolovskaya, 2008). Pelagic larvae of *K. punctatus* (60 ind.) *TL* 5.0–8.0 (on average, 6.5) mm were found in catches of the eastern site of the marine reserve at the end of July 2008 at surface water temperature of 19.0–22.0°C at six stations (no. 9, 16, 18, 19, 21, and 22). It is typical that our individuals were far smaller in size than individuals caught at the end of July 1994 over the water area of Amur Bay at a temperature of 22–26°C—55 ind. *TL* 10.0–30.0 mm (Sokolovsky and Sokolovskaya, 1994). Apparently, spawning of *K. punctatus* in 2008 took place later in the western part of Peter the Great Bay than in 1994 in Amur Bay. Shallow Amur Bay jutting out into the continent whose apex part is occupied by estuary water masses in summer warms up earlier than the deeper western part of Peter the Great Bay, whose temperature regime is formed by coastal surface and subsurface water masses (Biryulin, 1970).

The most numerous southern component of ichthyoplankton in the studied area was *E. japonicus*. Its spawning in Peter the Great Bay takes place from May to the first half of October at a water temperature of 14–19°C (Sokolovsky and Sokolovskaya, 2008; Gnyubkina et al., 2013). From June to August 2007–2009, eggs of this species at all stages of development were recorded in catches—on average, 12 ind./catch; frequency of their occurrence varied from 18.2 to 100%. Maximum numbers of larvae of *E. japonicus* were observed in August 2009 when frequency of occurrence was 100% and more than 20000 ind. *TL* 3.5–17.0 mm were caught. High concentrations of *E. japonicus* (up to 4000 ind./catch) were recorded at almost all 11 stations (Fig. 2).

In ichthyoplankton of the coastal zone of the western part of Peter the Great Bay in 2007–2010, one species of fish—*Cololabis saira*—was represented by all age groups. This species in waters of Primorye in the summer period occurs uniformly (Novikov, 1956). According to our data, arrivals of juveniles of *C. saira* to the water area of the marine reserve were recorded at the end of June; at increase in water temperature above 20°C (at the beginning of August), it moves off to more out at sea sites of Peter the Great Bay. Spawning season of this species is extremely extended (Sokolovsky et al., 2000). In our catches, eggs at I–III stage of development with diameter of 1.5–2.0 mm, as well as larvae and fry *TL* 5.5–21.0 mm, occurred in July. A total of 2000 ind of *C. saura* were caught, and maximum concentrations (>300 ind./catch) were at station nos. 2, 6, and 22.

Thus, eggs, larvae, and fry of pelagophilic species whose main spawning takes place in June–July were dominant in summer months of 2007–2010 over the water area of the eastern site of the marine reserve

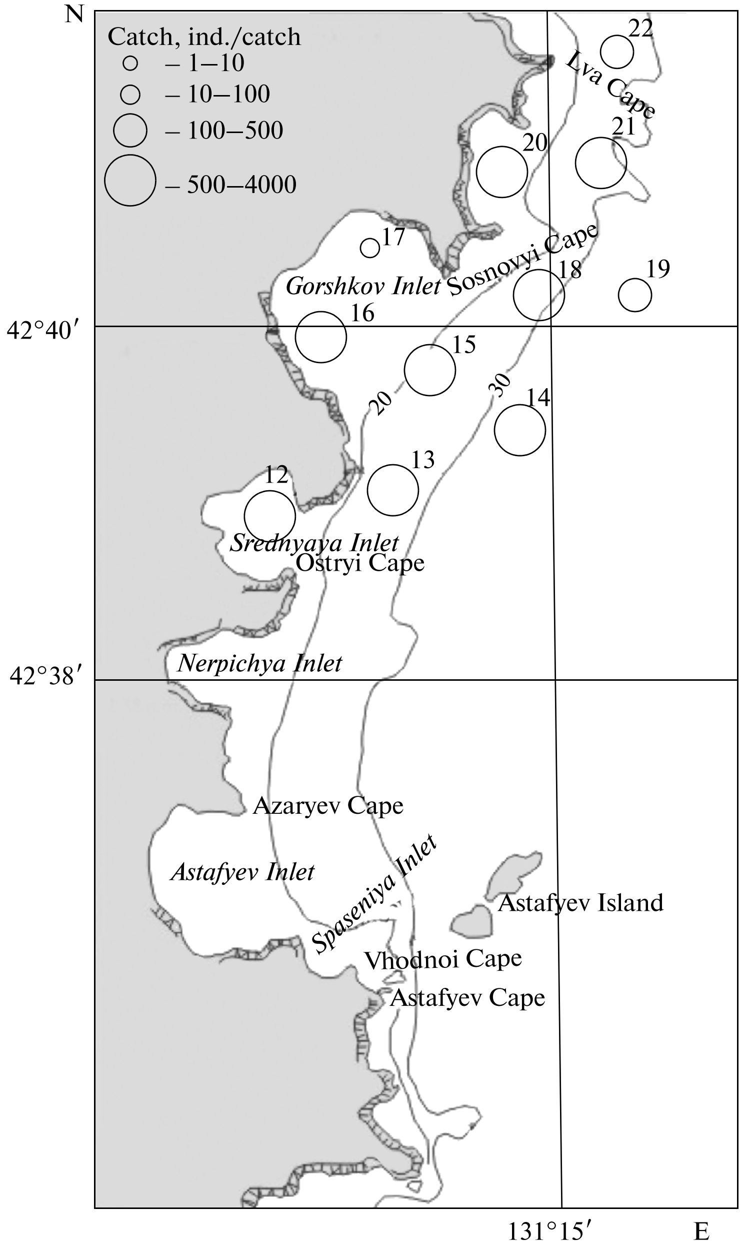

Fig. 2. Distribution of larvae and fry of *Engraulis japonicus* over the water area of the eastern site of the marine reserve (DVMB-GPZ DVO RAN) in August 2009; see designations in Fig. 1.

(Davydova, 1994, 1998; Sokolovsky and Sokolovskaya, 2008; Epur and Balanov, 2011).

In September in ichthyoplankton samples, no larvae and fry of thermophilic fish were found, and the number of resident species was minimal—only two (Table 2). These are representatives of the family Hexagrammidae—*Hexagrammos stelleri* and *H. octogrammus*—bottom fish inhabiting coastal waters of the northern part of the Pacific Ocean (Antonenko and Puschina, 2002). At the end of October, in the period of cooling of waters before winter, in ichthyoplasnkton of the eastern site of the marine reserve, only two species of fish were recorded—*Pleurogrammus azonus* and *H. octogrammus*.

Having supplemented our own data by materials from published sources, we managed to trace the seasonal dynamics of ichthyoplankton of the coastal zone of the western part of Peter the Great Bay. In May, maximum species diversity—52 species—is observed. In the summer period, decrease in the number of species is observed: 14 species in June, 19 species in July, and 10 species in August. In autumn, catches of ichthyoplankton here are poor and homogeneous: two species each in September and October. This is explained by the fact that the most part of the resident

Table 4. Number of families and species of fish in the water area of the eastern site of the marine reserve (DVMBGPZ DVO RAN) in May–October 2007–2010 according to data of catches of egg net IKS-80 and collections at light stations

Family	Month					
	V	VI	VII	VIII	IX	X
Clupeidae	1	1	2	–	–	–
Engraulidae	–	1	1	1	–	–
Osmeridae	1	1	–	–	–	–
Salangidae	1	–	–	–	–	–
Gadidae	2	1	–	–	–	–
Scomberesocidae	–	–	1	–	–	–
Hemirhamphidae	–	–	1	–	–	–
Syngnathidae	–	–	2	1	–	–
Sebastidae	–	2	4	3	–	–
Hexagrammidae	1	–	–	–	2	2
Cottidae	12	–	–	–	–	–
Hemitripteridae	3	–	–	–	–	–
Psychrolutidae	1	–	–	–	–	–
Agonidae	5	–	–	–	–	–
Cyclopteridae	1	–	–	–	–	–
Liparidae	2	–	–	–	–	–
Mugilidae	–	–	1	–	–	–
Zoarcidae	1	–	–	–	–	–
Stichaeidae	12	1	–	–	–	–
Pholidae	2	1	–	–	–	–
Cryptacanthodidae	1	–	–	–	–	–
Trichodontidae	1	–	–	–	–	–
Callionymidae	–	–	–	1	–	–
Gobiidae	–	–	2	2	–	–
Pleuronectidae	5	6	5	2	–	–
Total species	52	14	19	10	2	2
Total families	17	8	9	6	1	1

ichthyofauna of Peter the Great Bay is represented by species of boreal and arctic-boreal origin, whose spawning takes place at a relatively low water temperature and is confined, as a rule, to autumn–winter and winter–spring periods (Tokranov, 1986; Maeda and Amaoka, 1988; Amaoka et al., 1989; Panchenko, 2001a, 2001b; Kolpakov and Dolganova, 2006).

If a drastic decrease is traced by the number of species from spring to summer, the number of families representing these species from May to August changes gradually from 17 to six (Table 4). This can be explained by the fact that subspecies families present in spring ichthyoplankton in the summer period are replaced by families represented in ichthyoplankton by one or more seldom two species. Resident species (representatives of families such as Pleuronectidae, Sebastidae, and Hexagrammidae) and representatives of the family Clupeidae are found for a prolonged time (3–4 of 6 months). For the southern migrant *E. japonicus*, besides occurrence in mass, rather prolonged presence in ichthyoplankton is also typical (3 of 6 months).

Noteworthy are also facts of interannual changes in the qualitative and quantitative composition of the ichthyoplankton community of the coastal zone of the western part of Peter the Great Bay. For instance, 6, 16, 9, and 16 species were recorded in ichthyoplankton collections of the eastern site of the marine reserve in July 2007, 2008, 2009, and 2010, respectively. One can suppose that these changes in the qualitative composition of ichthyoplankton are determined by interannual changes in surface water temperature. Analysis of data on its dynamics allowed us to reveal two types of summer: cold (2007 and 2009) and warm (2008 and 2010). Average monthly water temperature, as well as the limits of its variation, in cold summer is approximately by

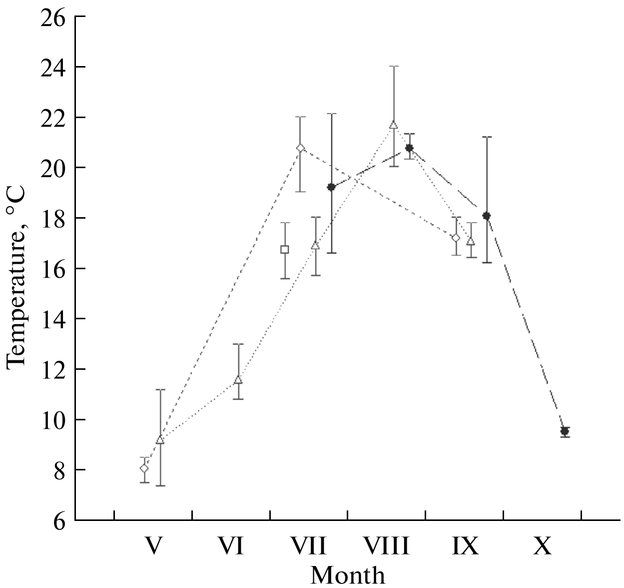

Fig. 3. Seasonal change in temperature of surface waters (average, minimal, and maximum values) of the eastern site of the marine reserve (DVMBGPZ DVO RAN) in May–November 2007–2010. Average values: (□)–2007, (···○···)–2008, (····△····)–2009, (–●–) 2010.; (I) limits of index variation.

3°C lower than in warm summer—16.9 (15.6–17.9) vs. 20.1 (17.8–22.1°C) (Fig. 3). A direct relationship between temperature of surface waters and numbers of ichthyoplankton is traced from this, namely, temperature drop leads to impoverishment of the qualitative composition of ichthyoplankton community.

As is seen from the above-mentioned materials, the coastal zone of the western part of Peter the Great Bay plays an important role in reproduction of many commercial and noncommercial species of fish–inhabitants of coastal shallow waters. It was established that there are 77 species of fish belonging to 25 families in ichthyoplankton of the coastal zone of the western part of Peter the Great Bay, which comprises 24.4% of the total number of species of fish inhabiting Peter the Great Bay (Davydova, 1994; Epur et al., 2008; Kosyanenko et al., 2013). Maximum species diversity was recorded in ichthyoplankton of the eastern site of the marine reserve—60 species or 19.0% of the total number of species inhabiting Peter the Great Bay. Here, orders Scorpaeniformes and Perciformes include maximum number of taxa. Highest species diversity of ichthyoplankton is observed in May—52 species (from 17 families)—then the number of species gradually decreases: from 14 species (eight families) in June to two species (one family) in October.

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