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Distribution, Size Composition and Feeding of the Barred Snailfish *Crystallias matsushimae* (Liparidae) in the Russian Zone of the Sea of Japan

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Abstract—The results of studying the bathymetric and spatial distribution of the barred snailfish *Crystallias matsushimae* are presented according to bottom trawl surveys in the Russian waters of the Sea of Japan. The species does not form dense aggregations, although it is not as rare as was previously thought: in bottom trawl catches on the continental slope, the frequency of its occurrence is about 30%. The main areas of the species aggregations are the western part of the Peter the Great Gulf and the deep-water section of the Tatar Strait between the mainland and Sakhalin Island. Despite the relatively wide range of water temperature and depths at which the snailfish was found in catches, the species prefers rather narrow thermal and bathymetric ranges: 0.6–1.5°C and 200–500 m. Mysids, amphipods and decapods dominate in the diet.

Keywords: barred snailfish *Crystallias matsushimae*, Liparidae, distribution, biomass, feeding, Sea of Japan

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INTRODUCTION

The barred snailfish *Crystallias matsushimae* Jordan et Snyder 1902 is a common representative of the family Liparidae and the only representative of the genus *Crystallia* found in the Sea of Japan. Sometimes the genus *Crystallia*s Jordan et Snyder, 1902 is referred to as a junior synonym of the genus *Crystallichthys* Jordan et Gilbert, 1898 (Chernova et al., 2004), however, according to modern concepts, it is a valid species (Parin et al., 2014; Fricke et al., 2023).

The species is widespread in the Sea of Japan, around the Japanese Archipelago and the Kuril Islands, in the southern part of the Sea of Okhotsk (Song Yong Ho, 1986; Pitruk, 1990; Borets, 1997, 2000; Fedorov and Parin, 1998; Fedorov, 2000; Novikov et al., 2002; Nakabo, 2002; Kim et al., 2005; Sokolovsky et al., 2007, 2011). Some researchers report the capture of the species in the southern part of the Bering Sea, which significantly expands the boundaries of its habitat (Lindberg and Krasyukova, 1987; Parin et al., 2014). The data on the biology of barred snailfish are scarce and they are fragmentary both for the Sea of Japan and for the rest of the range.

The species differs from the other representatives of the family in the presence of elongated vertical stripes on the body and large barbels on the lower jaw and snout. Characteristic elongated ring-shaped spots are clearly visible even in small-sized (from 17.8 mm long) fish (Matsuzaki et al., 2022), which is not observed in other liparids in the Sea of Japan. Due to the relatively easy identification of liparid species, we were able to use a large bulk of data on the biology of this species without fear of their confusion with other species of the family.

The aim of the work is to study the bathymetric and spatial distribution of barred snailfish in the northwestern part of the Sea of Japan, to assess the influence of the temperature of the bottom water layer on the features of its distribution, to determine the size composition and diet and to give quantitative estimates of the species.

MATERIALS AND METHODS

The study is based on the data of bottom trawl surveys conducted on the shelf and the continental slope in the northern part of the Sea of Japan during the cruises of TINRO research vessels in 1978–2018. The water area was divided into four regions: the Peter the Great Gulf (PGG), from the Tumannaya River to Cape Povorotny, Northern Primorye (NP), from Cape Povorotny to Cape Zolotoy, the waters off the mainland coast of the Tatar Strait (TS), from Cape Zolotoy to the Nevelskoy Strait and Western Sakhalin (WS), off the island coast of the Tatar Strait, from the

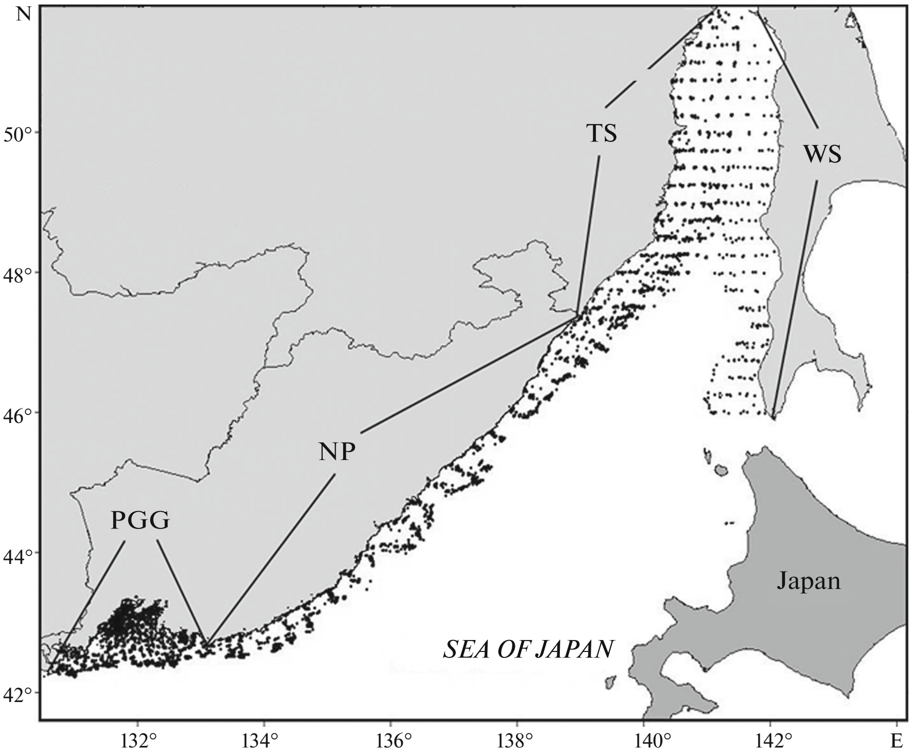

Fig. 1. A schematic map of surveys in the Sea of Japan in 1978–2018: (●) trawl stations, PGG, Peter the Great Gulf, NP, Northern Primorye, TS, Tatar Strait, WS, Western Sakhalin.

Nevelskoy Strait to Cape Crillon (Fig. 1). The depths of 20–750 m were studied (in the Peter the Great Gulf, from 2 m). When analyzing the seasonal distribution, the hydrological seasons were distinguished according to the classification of Zuenko (1994): the winter period includes January and February, the spring season includes March and April, summer includes June–September, and autumn includes November and December. May is a transitional month between spring and summer seasons, October, between summer and autumn. We attributed May to the spring season, October to the autumn season.

Vessels of various classes and different types of trawls with a fine-mesh insert (10 mm) at the codend were used in the surveys. The DT/TV 27.1 bottom trawl was predominantly used.). To build maps of spatial distribution, catches were averaged over squares with a side of 10 geographical minutes. The fish biomass was determined by the swept area method (Aksyutina, 1968) with a catchability coefficient of 0.5 (Gavrilov et al., 1988). The data of 50 surveys were used in the study (PGG, 23, NP, 13, TS, 12, WS, 2). The total number of the surveyed trawl stations was 14839 (Table 1), barred snailfish was recorded at 1643 stations of them. The total body length (*TL*) was measured in fish from the catches. Measurements were made of 1256 ind., of which 610 ind. were weighed.

The material on feeding of snailfish (76 stomachs) was collected in the waters of Northern Primorye (at depths of 60–450 m) in April–May. The samples were processed in accordance with the Methodological manual (1974). The value of the daily ration of fish was estimated by the Novikova (1949) method modified by Chuchukalo and Napazakov (1999) by determining the duration of digestion of the initial (reduced) mass of food items depending on the temperature of the bottom water layer. The average ration and the ratio of food components are calculated taking into account the biomass of the studied size groups and their contribution to total consumption.

RESULTS

Bathymetric distribution. The barred snailfish *Crystallias matsushimae* live in a relatively wide range of depths, from 30 to 749 m. The preferred depths were 201–500 m in the upper section of the continental slope (Fig. 2). In summer and autumn, its aggregations were confined to the boundary of the shelf zone with depths of 201–300 m, in winter and spring they were found at larger depths, 401–500 m. Barred snailfish is a typical representative of the mesobenthal biotope.

According to the frequency of occurrence, barred snailfish belongs to the common species on the continental and island slopes; at depths of 201–500 m it was found in about a third of catches (Table 1). It was recorded to a lesser extent at depths of 501–700 m (20.3%) and within the shelf zone.

Table 1. The total number of trawl operations performed in the Russian waters of the Sea of Japan in different seasons 1978–2018, and the frequency of occurrence (FO) of the barred snailfish *Crystallias matsushimae* by depths

Depths, m	Spring	Summer	Autumn	Winter	Total	FO, %
1–5	3	80	23	0	106	0
6–20	76	1193	211	2	1482	0
21–50	715	2030	361	52	3158	0.2
51–100	1086	1823	419	189	3517	4.2
101–200	1103	665	316	257	2341	12.1
201–300	818	328	275	166	1587	29.6
301–400	614	167	164	121	1066	32.6
401–500	468	103	130	104	805	30.7
501–700	329	124	218	18	689	20.3
701–1000	69	1	18	0	88	4.5
Total	5281	6514	2135	909	14839	

Spatial distribution. Barred snailfish was recorded in all surveyed areas in the Russian zone of the Sea of Japan. It did not form dense aggregations; the maximum catch was 66 kg/h of trawling.

The smallest number of trawling operations was performed in winter, so the distribution pattern at this time of the year does not cover a significant part of the study water area (Fig. 3a). The species was found throughout the entire water area of Northern Primorye, but high catches were recorded in the western part of the Peter the Great Gulf. Trawl surveys were not conducted both on the mainland and on the island sides of the Tatar Strait in winter.

In spring, barred snailfish avoided shelf zones (Fig. 3b). In the Peter the Great Gulf it kept along the continental slope, forming aggregations in the western part of the gulf in coordinates 42°20′ N, 131°20′ E in the area of the so-called Gamov's slope. In Northern Primorye, where the shelf zone is not developed, this species was found in catches almost from the shoreline. The distribution was rather uniform. Northward, with the expansion of the shelf, the catches shifted to depths towards the steep slope between the mainland and Sakhalin Island. Snailfish were not recorded in the shallow part of the Tatar Strait, north of 50° N in spring. Along the island coast of Sakhalin, the species was not numerous and also avoided shelf zones.

In summer, snailfish reached the shelf areas (Fig. 3c). This was especially evident in the Peter the Great Gulf, where it was recorded in catches in the open part and even entered the bays of the second order (Ussuri Bay). The species was also repeatedly recorded in bottom trawl catches in the upper part of the Tatar Strait (north of 50° N). However, in general, it continued to stay preferably on the continental slope, without forming large aggregations.

In autumn, barred snailfish formed aggregations of high density along the continental slope of the Peter the Great Gulf and in the deep-water part of the Tatar Strait between the mainland and Sakhalin (Fig. 3d). In

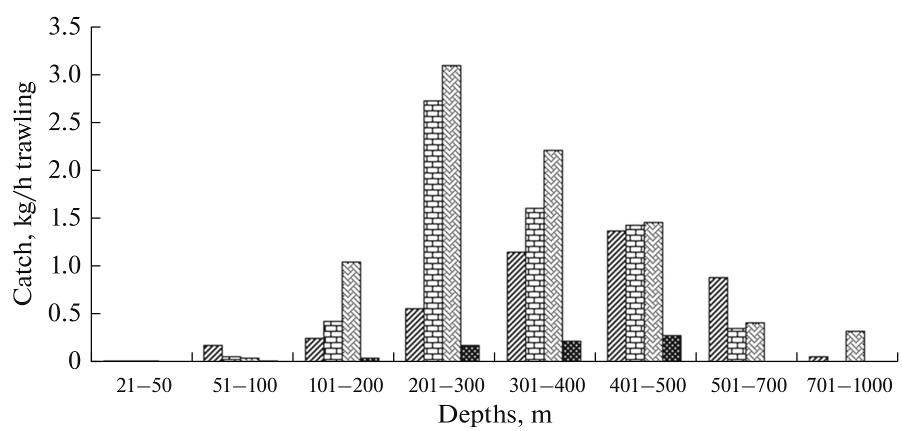

Fig. 2. Distribution of catches of the barred snailfish *Crystallias matsushimae* in the Russian waters of the Sea of Japan by depths in different seasons 1978–2018: (▨)—spring, (▤)—summer, (▧)—autumn, (■)—winter.

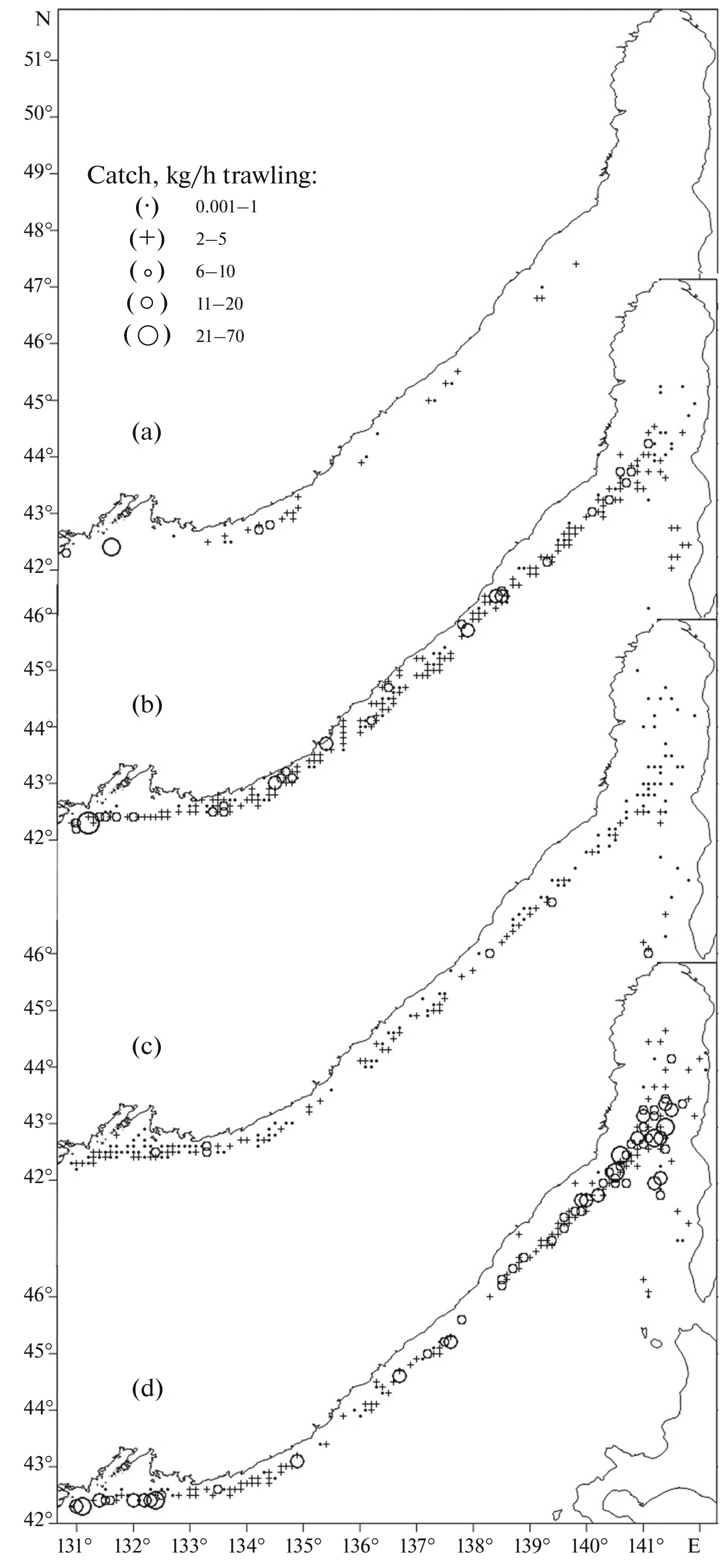

Fig. 3. Distribution of catches of the barred snailfish *Crystallias matsushimae* in the Russian waters of the Sea of Japan in different seasons 1978–2018: (a) winter, (b) spring, (c) summer, (d) autumn.

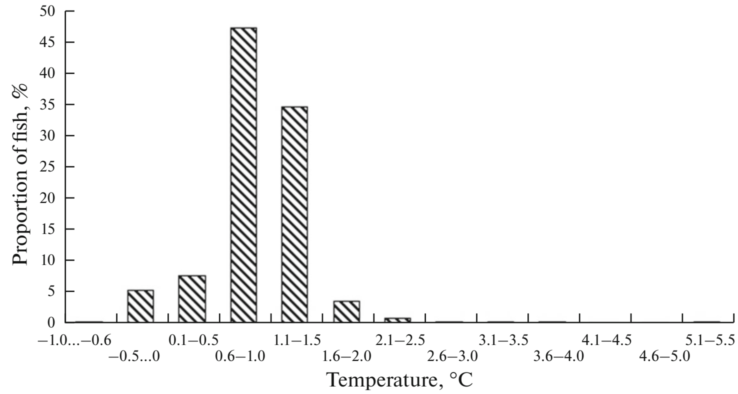

Fig. 4. Distribution of catches of the barred snailfish *Crystallias matsushimae* in the Russian waters of the Sea of Japan depending of the temperature of the bottom water layer.

Northern Primorye, relatively high catches of the species were also recorded in a narrow strip along the continental slope. At the same time, captures in the northern, shallow part of the Tatar Strait continued to be recorded in the same areas as in the summer.

In general, there are particular patterns in the distribution of snailfish in the northern part of the Sea of Japan during the year. In the Peter the Great Gulf, the species rarely enters the bays of the second order, preferring to stay at the outer edge of the shelf. There it forms quite dense aggregations in the western and eastern parts of the gulf, where there are sections of the bottom with a steep slope. In Northern Primorye, the sites of aggregations of the species were not, as a rule, distinguished, the catches were performed throughout the area. Northward, with the expansion of the shelf, the species' captures shifted to the central part of the Tatar Strait, where the maximum concentrations were recorded. Along the Sakhalin coast, barred snailfish was found sporadically, it was absent in areas with a wide shelf, and its increased concentrations were recorded at the slope on the island side.

Dependence of the distribution on the bottom water layer temperature. Barred snailfish is a stenothermic species. Some of its captures were recorded at water temperatures from –0.8°C in February on the shelf of the Peter the Great Gulf to 5.4°C in the waters of Northern Primorye. However, the species mostly stayed in a narrow temperature range, more than 80% of his catches were within one degree, from 0.6 to 1.5°C (Fig. 4).

Size composition. Individuals of barred snailfish *TL* 6–45 cm were recorded in bottom trawl catches. The modal group included fish *TL* 30–32 cm (Fig. 5a). The length–weight relationship of this species from the waters of the Sea of Japan was described by the equation: $W = 0.0141\,TL^{3.0292}$ ($R^2 = 0.937$), where W is the weight of fish, g; *TL* is the total length, cm (Fig. 5b).

Long-term dynamics of biomass. Since the early 2000s, the average biomass of barred snailfish in different areas has been approximately the same, 350–450 t. The maximum estimates of the stock in Northern Primorye and Western Sakhalin exceeded 800 t, and in 2014, reached 1033 t along the mainland coast of the Tatar Strait (Fig. 6). The average and maximum values of stock assessments in the Peter the Great Gulf were much lower and accounted for 108 and 426 t, respectively. Since the early 2000s, the biomass of barred snailfish has increased in the northern part of the Sea of Japan, the peak of its biomass in the Peter the Great Gulf occurred in 2010–2012, and in the other regions, in 2013–2016.

Feeding. According to our data, barred snailfish is a nectobenthophage and its diet is mainly formed by two groups of forage organisms such as amphipods (Amphipoda) and mysids (Mysida) (in total 85.6%) (Table 2).

The proportion of decapods (Decapoda) and polychaetes (Polychaeta) was the most significant among the minor components of its food. The juveniles of snailfish *TL* 11–20 cm preferred benthic invertebrates: amphipods (mainly of the genus *Syrrhoe*) and polychaetes of the family Polynoidae. As snailfish grew, the role of benthos (especially polychaetes) in the diet decreased considerably, but the role of nectobenthos, mainly mysids *Inusitatomysis insolita* and decapods (mainly shrimps of the genus *Spirontocaris* and crangonid shrimps *Mesocrangon intermedia* increased.

In addition, a small amount of euphausiids of the genus *Thysanoessa* and juveniles of cottids (Cottidae) and eelpouts (Zoarcidae) were found in the food of individuals *TL* 21–40 cm.

Along with the size and age, the bathymetric variability of feeding is well expressed in barred snailfish. On the shelf, mysids (58.8% of weight) dominated in the diet but due to a significant increase in the amphipod consumption as the depth increased, the propor-

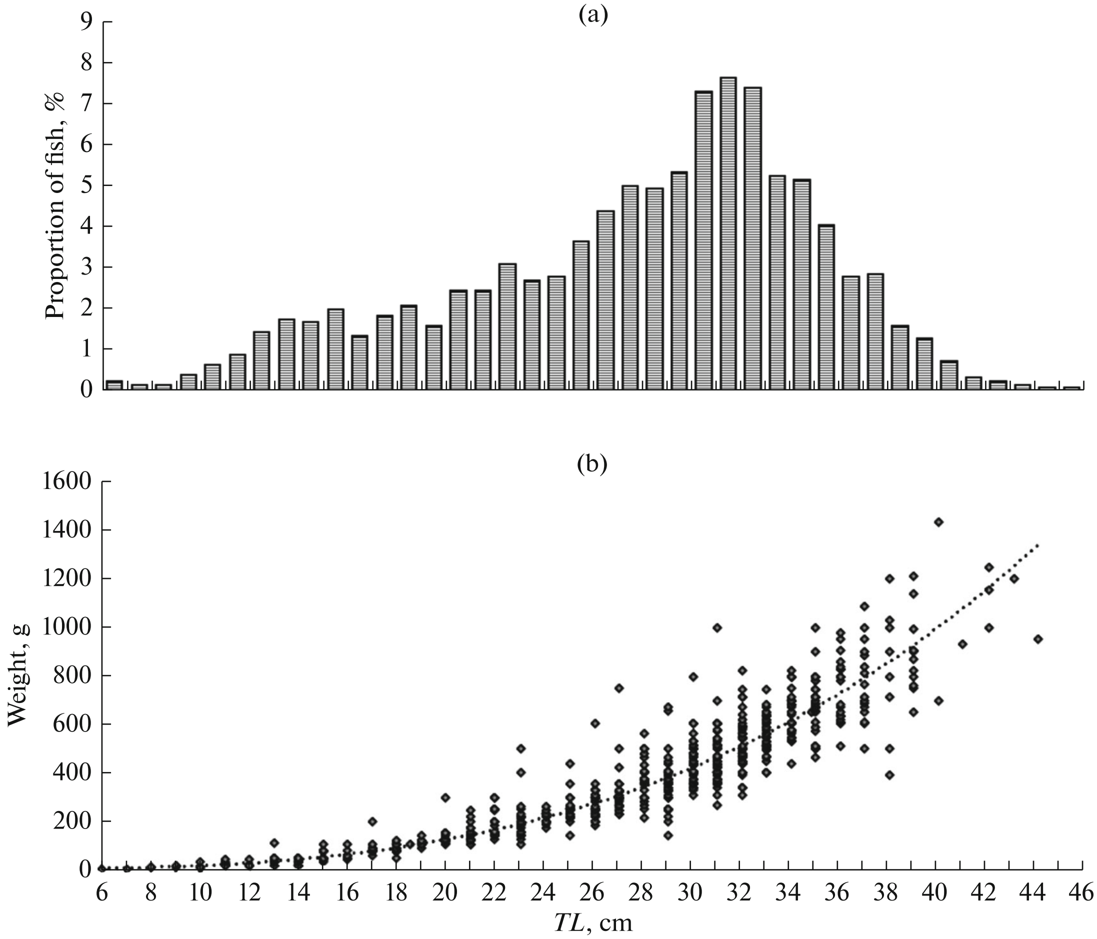

Fig. 5. Size composition (a) and relationship between the body weight and total length (*TL*) (b) of the barred snailfish *Crystallias matsushimae* in trawl catches in the north-western part of the Sea of Japan in 1978–2018.

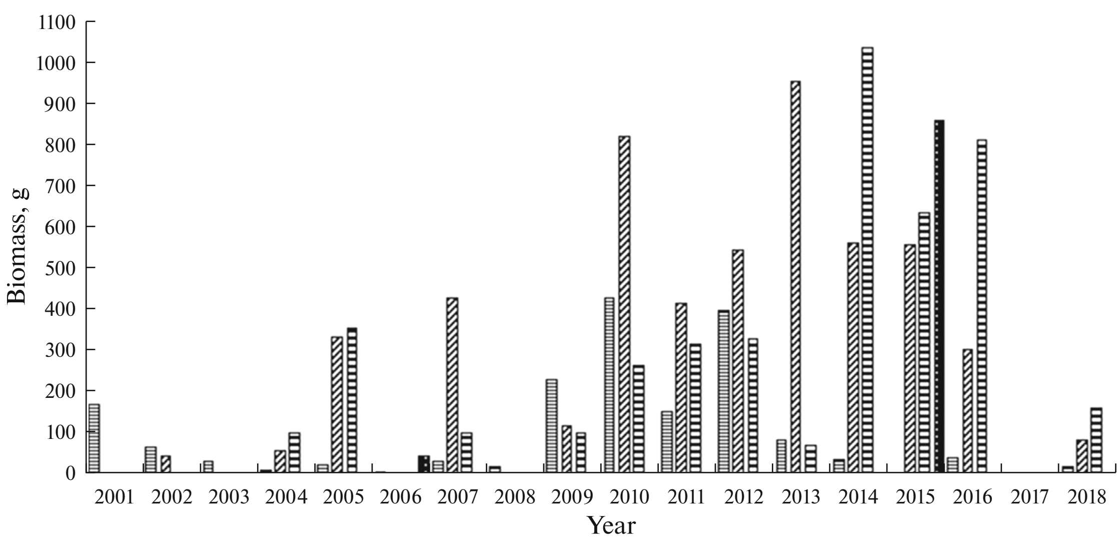

Fig. 6. Long-term dynamics of the barred snailfish *Crystallias matsushimae* in different regions of the north-western part of the Sea of Japan according to the data of trawl surveys: (▤)—Peter the Great Gulf, (▨)—Nothern Primorye, (▤)—Tatar Strait, (▦)—Western Sakhalin.

Table 2. Diet composition of the barred snailfish *Crystallias matsushimae* of different size in waters off Northern Primorye (April–May), % of weight

Food component and other parameters	Size group, cm			On average
	11–20	21–30	31–40	
Polychaeta	29.2	1.9	1.4	2.4
Polynoidae gen. spp.	29.2	0.9	1.4	1.8
Polychaeta varia		1.0		0.6
Isopoda	2.9	1.2	+	0.8
Amphipoda	64.6	47.3	20.1	36.0
Rhachotropis aculeata		1.2	9.2	4.6
Rh. oculata	5.8	20.9	3.2	12.8
Stegocephalus inflatus			2.1	0.9
Metopa majuscula		0.2	1.1	0.8
Syrrhoe crenulata	4.6	0.2	0.1	0.3
Syrrhoe sp.	44.2	23.3	2.2	14.8
Caprella sp.	10.0	0.9	0.5	0.9
Amphipoda varia		0.6	1.7	0.9
Mysida	3.3	45.4	57.6	49.6
Inusitatomysis insolita		37.9	47.4	41.0
Pseudomma sp.	3.3	6.6	10.2	8.1
Mysida varia		0.9		0.5
Euphausiacea		0.6	2.6	1.4
Decapoda		2.5	14.0	7.4
Spirontocaris arcuata			1.8	0.8
S. brevidigitata		0.3	2.1	1.0
S. phippsii		0.2	1.9	0.9
Mesocrangon intermedia		1.5	5.5	3.2
Pagurus sp.			2.7	1.2
Decapoda varia		0.5		0.3
Pisces		1.1	3.7	2.2
Others		+	0.6	0.2
Average daily ration, % of body weight	2.5	2.0	1.4	1.7
Number of stomachs, pcs.	5	48	23	76
Proportion of empty stomachs, %		2.1	17.4	6.6

"+", proportion of the component < 0.1%.

tion of mysids, as well as the proportion of secondary components, decreased, as a result of which amphipods and mysids were equally important in the diet on the continental slope (48.4 and 44.2%, respectively) (Fig. 7). The differences are probably related to bathymetric changes in the structure of the food base of barred snailfish , however, due to the poor knowledge of this issue, it is not possible to judge this more definitely.

According to our calculations, the average daily diet of individuals of barred snailfish *TL* 11–40 cm in the spring period was 1.7% of body weight and decreased from 2.5 to 1.4% as they grew (Table 2). The intensity of feeding of the species on the continental slope (2.1%) is higher than on the shelf (1.2%).

DISCUSSION

According to some authors (Sokolovsky et al., 2011; Parin et al., 2014) barred snailfish is considered a rare species. Apparently, this is due to the fact that the results of surveys at shallow depths were considered. According to the materials of our study, this species was found only in 0.2% of catches at depths up to 51 m, and in 4.2% in the range of 51–100 m. But if we consider fish of the mesobental habitat, barred snail-

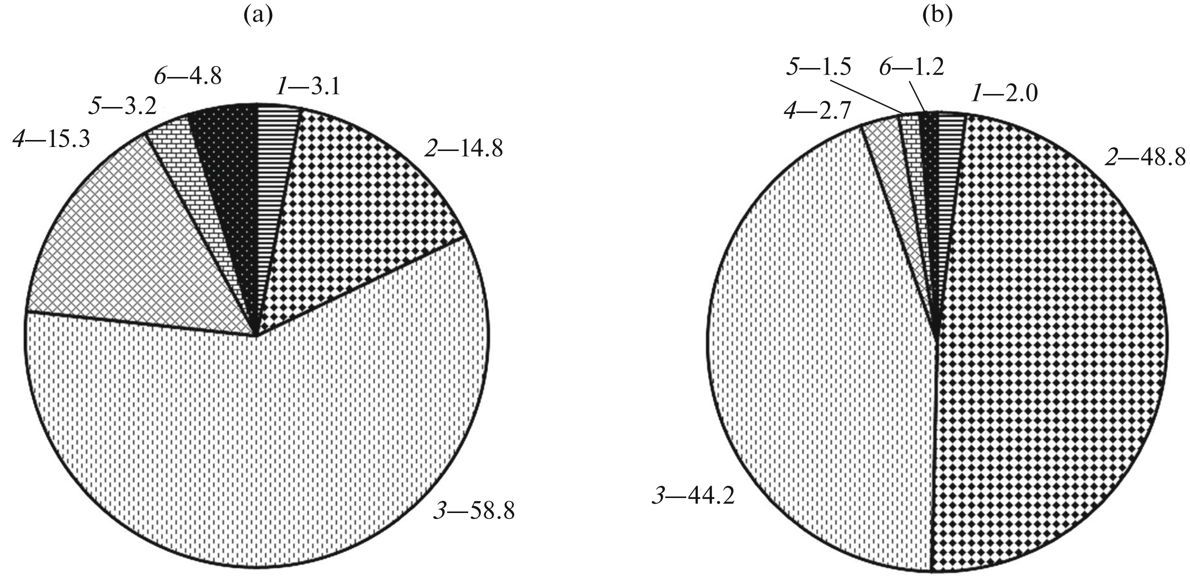

Fig. 7. Diet composition (% of weight) of the barred snailfish *Crystallias matsushimae* on the shelf (a) and continental slope (b) of Northern Primorye in April –May: (*1*) Polychaeta, (*2*) Amphipoda, (*3*) Mysida, (*4*) Decapoda, (*5*) Pisces, (*6*) others.

fish is a common species there, and is recorded in almost every third catch by the bottom trawl.

According to our data, barred snailfish is characterized by a sedentary lifestyle; it does not perform long migrations either in the latitudinal or bathymetric directions. Despite the wide range of depths at which its captures were recorded, the species mostly preferred the upper section of the continental slope (201–500 m). Apparently, it is characterized by migrating to great depths in winter. Its significant concentrations were recorded in the range of 401–500 m in winter and spring, as well as high catches at depths of 501–700 m. Savin (2014) classifies the barred snailfish as a mass species in waters off the Southern Kuriles in the range of 300–400 m in the spring period. Probably, the different hydrological conditions and the abundance of deep-sea fish species (primarily *Macrourus* species that are absent in the Sea of Japan) lead to the fact that there barred snailfish is characterized by a narrower vertical range of habitation, and it winters at lower depths than in the zone of the Sea of Japan.

In summer and autumn, barred snailfish prefers depths of 201–300 m. At this time, it is dispersed and does not form dense aggregations, and its concentrations increase in the autumn period, so that it is in autumn that the highest catches of this species are recorded throughout the year (Fig. 1).

Ssnailfishes are s characterized by large eggs (4–5 mm in diameter) and the absence of a pelagic larval stage, which also leads to a narrowing of the zone of their migration (Tohkairin et al., 2015). These authors suggest that such a sedentary lifestyle in the absence of geographical barriers led to the emergence of two morphs of snailfish in the Sea of Japan, yellow and red morphotypes. The Russian zone of the Sea of Japan is included in the segment where only the red morph lives; in the expeditions in which we participated, not a single individuals of the yellow morph was captured.

In Northern Primorye, catches of barred snailfish were recorded near the coastline, unlike the other areas of the northern part of the sea. Apparently, the reason is the same as for some other species that live mainly on the continental slope, for example, the dragon poucher *Percis japonica* (Pallas, 1769) (Solomatov and Antonenko, 2023). The absence of a wide shelf zone in this part of the Sea of Japan allows the fish not to perform long migrations in order to reach the minimum habitat depths.

Adult individuals of barred snailfish of the model size group 30–32 cm prevailed in the bottom trawl catches. This may be due to various reasons. First, it can be explained by the selectivity of the bottom trawl: small fish are simply not caught and pass through the meshes of the trawl wings. Secondly, due to its sucking disc, which is relatively larger in small individuals (Lindberg and Krasyukova, 1987), snailfishes can attach to the ground and are not caught by trawl (Panchenko and Pushchina, 2022).

Most of the studied species of snailfishes are classified as bentho- or nektobenthophages by the feeding habits (Tokranov, 2000; Chuchukalo, 2006; Tokranov and Orlov, 2014). Having a relatively low average daily diet and biomass relative to most fish of the mesobenthal biotope, the proportion of barred snailfish in grazing different aquatic organisms on the continental slope of the Sea of Japan is insignificant. According to the composition of the diet among the mass and common fish species of the shelf and the continental slope of Northern Primorye, barred snailfish has the maximum similarity with the Okhotsk snailfish *Liparis ochotensis* Schmidt, 1904, the Gilbert's Irish lors *Hemilepidotus gilberti* Jordan et Starks, 1904 and the saffron *cod Eleganus gracilis* (Tilesius, 1810) (Pushchina and Solomatov, 2018).

CONCLUSIONS

The barred snailfish is a common species in the northern part of the Sea of Japan, where its frequency is ~30%. At the same time, its biomass only in some years exceeds 800 t in different studied areas, usually being at the level of 350–450 t. The main areas of aggregations of barred snailfish in the Sea of Japan are the continental slope of the Peter the Great Gulf and the central part of the Tatar Strait.

In the waters off Northern Primorye, barred snailfish is a nectobenthophage, forming its diet mainly due to two groups of invertebrates, amphipods (36.0%) and mysids (49.6%). As snailfish grows, the role of benthos (amphipods, polychaetes) in its diet decreases and the role of nectobenthos (mainly mysids and decapods) increases. In the spring, the average daily diet is 1.7% of body weight, while the feeding rate of the species on the continental slope is higher than on the shelf (2.1 and 1.2%, respectively).

Despite the relatively wide range of water temperature and depths at which barred snailfish was found in catches, the species prefers rather narrow thermal and bathymetric ranges: 0.6–1.5°C and 200–500 m.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Commission on Biomedical Ethics of the Zhirmunsky National Scientific Center of Marine Biology, Far Eastern Branch, Russian Academy of Sciences confirms that the experimental procedures carried out with fish comply with all current Russian and international legal norms and regulations for conducting research with laboratory animals (protocol no. 1-111223 of December 11, 2023).

CONFLICT OF INTEREST

The authors of this work declare that they have no conflict of interest.

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