Impact of eddies on spatial distributions of groundfishes along waters off the northern Kuril Islands, and southeastern Kamchatka (north Pacific Ocean)

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Received 11 March 2002, revised 3 March 2003

Distribution peculiarities of groundfishes, inhabiting the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, where three quasi-stationary eddies occur, are considered in this paper. The possible influence of eddies on occurrence of groundfishes are discussed. Existing eddies off underwater plateau and small banks in the southern part of the study area provides specific environment (bottom relief, temperature, and currents) for fish inhabitation essentially differed from that of adjacent waters. Composition of ichthyofauna, off plateau area, is very specific. There are several species widely distributed in the North Pacific that were caught only within plateau area. Some species widely distributed within the Pacific waters off the Kuril Island and eastern Kamchatka are abundant only in the area off plateau and banks. Feeding aggregations of plankton-feeders Atka mackerel and Pacific Ocean perch (these species are targets of specialized fishery) occur here throughout the year, probably related to fine foraging conditions in the enlarged plankton biomass in the area. Pelagic larvae and juveniles of some fishes, permanently dwelling the area, probably grow there until settlement. The study area serves as nursery ground for some fishes, which spawn outside the area. Currents transport pelagic larvae and juveniles of these species from main spawning grounds (eastern Kamchatka and Paramushir Island coasts) to the south. The larvae fall into eddies, inhabit these waters until settlement, feed on plateau slopes and later with increase in size start reverse migrations. Thus, eddies affect occurrence and distributional patterns of various groundfish species, having different types of life cycle.

[ Key words : Distribution, eddy, groundfishes, underwater plateau, northern Kuril Islands, occurrence, southeastern Kamchatka ]

The Pacific waters off the northern Kuril Islands are one of the most productive areas of the Russian Far East EEZ2. However, the relative importance of fishes from this area in the total Russian Far East catch remained insignificant until now. In the 1980s, only 2.6-3.9 % (99 to 273.4 × 10³ tons) of the total annual fish harvest from the Russian Far East seas came from this area². Low catch was associated with rocky bottom that restricted bottom trawling in most of the area. Fishing in the area under consideration was conducted on grounds located mainly within the 12-mile coastal zone and in areas with a well-developed continental shelf. Commercially important fishes included walleye pollock Theragra chalcogramma, Pacific cod Gadus macrocephalus, northern rock sole Lepidopsetta polyxystra, and Atka mackerel Pleurogrammus monopterygius. Continental slope fishes (Greenland halibut Reinhardtius hippoglossoides, Kamchatka flounder Atheresthes evermanni, Pacific halibut Hippoglossus stenolepis, grenadiers Macrouridae, and rockfishes Scorpaenidae) did not exceed 2 % of the total catch².

Ichthyofauna of the Pacific waters off the northern Kuril Islands is poorly studied. Only recently, the completed lists of fishes, inhabiting the area considered, were published3,4. Until recently studies on distributional patterns and life histories of groundfishes, inhabiting the Pacific waters off the northern Kurils, were scanty5-7.

Oceanographic conditions of the Pacific waters off the northern Kuril Islands and southeastern Kamchatka are very dynamic due to interaction of East Kamchatka current with Strait's currents and bottom relief. As a result, two quasi-stationary anticyclonic eddies exist off the southeastern Kamchatka and Paramushir Island coasts8. Another eddy occurs in the area off the underwater plateau and several small banks that are located in the southern part of the northern Kuril Islands area (47°45'-48°55' N), southeast of Onekotan Island9. Relations between distributional features of key fish species from this area and some oceanographic characters (water structure and temperature, currents) were considered only by Kantakov10. There are no publications dealing with
effect of eddies on spatial distributions of groundfishes off the Kuril Islands.

The main objective of this study is to characterize spatial distribution of some groundfishes in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, to assess possible relations between character of their spatial distribution and the eddy existing over the underwater plateau in the southern part of investigated area, and to understand how these eddies affect spatial distributions and some biological features of several groundfish species.

Materials and Methods

This paper is based on catch data obtained from 21 bottom trawl surveys (total over 1,500 bottom trawl stations made during 1992-2000) and numerous bottom trawl hauls conducted during commercial operations from southeastern Kamchatka and northern Kuril Islands area (Fig. 1). The investigated area is within 47°30' N to 52° N, 154°20' E to 158°50' E (25,012 km²). Samples were collected from three chartered commercial Japanese trawlers (Tomi-Maru 53, Tomi-Maru 82, and Tora-Maru 58). Bottom trawl surveys were conducted during the daytime, commercial fishing operations were conducted round the clock at depths 76-833 m using a 5-7 m (vertically) by 25-30 m (horizontally) bottom trawl net constructed from 100-120 mm (stretched mesh) polyethylene net. The net was outfitted with steel and rubber ball roller gear in the forward wings. Only successful trawl samples (horizontal and vertical net openings remained within normal range, the roller gear maintained consistent contact with the bottom, the net suffered no or little damage during the tow, there were no conflicts with derelict fishing gear) were used for analysis in the present study. Most hauls were made along isobaths. Hauls with highly variable depths between the start and end of towing were excluded from the analysis.

On bottom trawl surveys the whole catch was analyzed. On the commercial fishing operations a representative sample was obtained from each trawl catch. These samples were taken for analysis from different parts of the catch (no less than 10% of total catch), sorted by species, and individuals counted and weighed. The rest of the catch was examined on the conveyer to note species not found in casual samples. Results were extrapolated to the total catch.

The frequency of occurrence for each species (FO, %) was calculated as a percentage of trawls in

![Fig. 1](https://via.placeholder.com/150)

**Fig. 1** — Maps showed locations of bottom trawl surveys (A) and commercial bottom trawl operations (B) conducted in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka aboard Japanese trawlers during 1992-2000 (broken lines are isobaths, I – Forth Kuril Strait, II – underwater plateau).
which this species was recorded. Catch per hour was calculated as average values of catches for each species standardized to a trawl duration of one hour, and expressed in numbers of fishes (ind.) per hour or weight (kg) per hour. Average catch per unit effort (CPUE) expressed in number or weight of individuals per unit of fishing effort was used to describe the relative abundance of a fish species.

Along the Pacific waters off the northern Kuril Islands and southeastern Kamchatka several eddies exist, which occurred to depths of 100-200 m. Some of them have stationary character in inter-annual and seasonal aspects. Data on localities of eddies and its spatial seasonal and inter-annual variations were taken from published sources \(^8\textsuperscript{,}10\textsuperscript{-}12\) and unpublished materials\(^13\). Consideration of oceanographic characters of eddies is not the objective of present study, but deals only with distributional patterns of groundfishes in relation to possible impact of eddies.

Results and Discussion

Differences of species composition between areas off and outside plateau

Ichthyofauna of the underwater plateau area that located in the southern part of study area is very specific. Its species composition considerably differ from that of other part of area investigated (Table 1). The study revealed that the number of groundfish species found in the plateau area is considerably lesser than those found outside plateau area (106 vs. 139). There are several species, widely distributed in the North Pacific Ocean, which were captured only off the plateau area and not from outside. These species are proboscis snailfish, scaled sculpin, nutracker prickleback, tough eelpout, fourhorn poacher, slime flounder. Most of spiny eel and skiffish specimens were caught within the plateau area and their capture outside plateau were incidental. On the other hand, there are about 40 groundfish species (mostly from families Cottidae, Agonidae, and Pleuronectidae), which were caught only from outside plateau area and not from within the plateau. However, the most significant distinctions between ichthyofaunas off and outside plateau areas were found in occurrence and relative abundance of species, belonging to the same families. Thus, grenadiers, Macrouridae (cumulative FO 83.8 % vs. 55.8 %, respectively), rockfishes, Scorpaenidae (218.4 % vs. 147.5 %), snailfishes, Liparidae (328.8 % vs. 275.9 %), and prowfishes, Zaproridae (12.1 % vs. 3.3 %) occurred from the plateau more frequently than outside. Opposite, outside plateau area, codfishes, Gadidae (cumulative FO 123.5 % vs. 41.7 %, respectively), sculpins, Cottidae, Hemilepidotidae, and Psychrolutidae (291.0 % vs. 236.8 %), poachers, Agonidae (96.8 % vs. 75.9 %), eelpouts, Zoarcidae (126.5 % vs. 75.7 %), and righteye flounders, Pleuronectidae (306.4 % vs. 141.7 %) were caught frequently in comparison with plateau area.

The possible reasons of above differences in occurrence of fishes off and outside plateau areas are due to distinctions in life history patterns of species considered. Most of fishes abundant off plateau prefer to inhabit areas with complex relief. They have pelagic eggs, larvae and juveniles that are feeding on plateau slopes. Sculpins inhabiting plateau area are represented by small-sized species of genera *Thyriscus*, *Rastrinus*, *Icelus*, *Archaulus*, which inhabit the areas with numerous sponges (Poryfera). It can be presumed that pelagic larvae and juveniles develop in eddy waters around underwater plateau until settlement. Eddy probably does not allow them to disperse outside this area, and as a result, distribution of these species are limited, as a rule, by surrounding underwater plateau waters. Moreover, sponges also have pelagic larvae\(^14\), whose development until settlement probably occurred in eddy waters.

Most of fishes abundant outside plateau also have pelagic eggs, larvae and juveniles. However, juveniles and adults of these species spawn, feed, and have maximum abundance in the areas with rather well developed shelf and smooth continental slope that are placed from the Fourth Kuril Strait to southeastern Kamchatka. Sculpins were represented by medium-sized and large-sized species from genera *Gymnocaenus*, *Hemilepidotus*, *Melletes*, *Myxoxcephalus*, *Hemilepidotus*, and *Uleca*, which spawn and feed within the shelf waters (similar to many other species from this group) and, migrate from lower shelf to upper continental slope areas, only during cold period.

Plankton-feeding species

Eddy waters due to its rich zooplanktonic biomass\(^15\) serve as feeding grounds for some plankton-feeding species such as Atka mackerel, Pacific Ocean perch, and prowfish.

Atka mackerel *Pleuragrammus monopterygius* inhabits mostly Pacific waters from the central Kuril Islands (Friza Strait) to the Gulf of Alaska including the Bering Sea. Its pelagic juveniles are feeding partly in the Sea of Okhotsk\(^16\). Dense concentrations of this
Table 1 — Frequency of occurrence (FO, %) of most abundant groundfishes in bottom trawl catches within (1) and outside (2) underwater plateau area

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<th>Scientific name*</th>
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<tr>
<td>Total number of species</td>
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<td>139</td>
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<tr>
<td>Total number of hauls</td>
<td>1038</td>
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**Rajidae**
- *Bathyraja aleutica* (Gilbert, 1896) Aleutian skate 50.2 45.5
- *B. maculata* Ishiyama et Ishihara, 1977 Whiteblotched skate 61.4 34.1
- *B. matsubarai* (Ishiyama, 1952) Matsubara skate 50.0 28.6
- *B. violacea* (Suvorov, 1935) Okhotsk skate 30.5 60.4

**Macrouridae**
- *Albatrossia pectoralis* (Gilbert, 1892) Giant grenadier 46.7 29.4
- *Coryphaenoides cinereus* (Gilbert, 1896) Popeye grenadier 37.1 25.1

**Moridae**
- *Antimora microlepis* Bean, 1890 Pacific flatnose 18.5 21.4

**Gadidae**
- *Gadus macrocephalus* Tilesius, 1810 Pacific cod 11.9 53.7
- *Theragra chalcogramma* (Pallas, [1814]) Walleye pollock 29.8 67.0

**Sebastes aleutianus** (Jordan et Evermann, 1898)
- *S. alutus* (Gilbert, 1890) Pacific ocean perch 40.4 26.2
- *S. borealis* Barsukov, 1970 Shortraker rockfish 65.0 33.2
- *Sebastolobus alascanus* Bean, 1890 Shortspine thornyhead 18.7 26.1
- *S. macrochir* (Günther, 1877) Broadbanded thornyhead 71.0 44.0

**Hexagrammidae**
- *Pleurogrammus monopterygius* (Pallas, 1810) Atka mackerel 33.9 41.6

**Cottidae**
- *Gymnacanthus detrisus* Gilbert et Burke, 1912 Purplegray scupin 4.0 26.6
- *Hemilepidotus jordani* Bean, 1881 Yellow Irish lord 0.9 23.0
- *H. zapus* Gilbert et Burke, 1912 Longfin Irish lord 30.2 1.7
- *Icelus canaliculatus* Gilbert, 1896 Blacknose sculpin 36.9 12.0
- *I. perminovi* Taranetz, 1936 Scaly-belly sculpin 24.0 2.2
- *Myxocephalus polyacanthocephalus* (Pallas, [1814]) Great sculpin - 27.4
- *Triglops scepticus* Gilbert, 1896 Spectacled sculpin 28.0 37.1

**Psychrolutidae**
- *Malacocottus zonurus* Bean, 1890 Darkfin sculpin 88.5 57.3

**Agonidae**
- *Bathyagonus nigripinnis* Gilbert, 1890 Blackfin starsnout 27.5 24.3
- *Sarritor frenatus* (Gilbert, 1896) Sawback poacher 38.3 37.5

**Liparidae**
- *Careproctus cypselurus* (Jordan et Gilbert, 1898) Falcate snailfish 19.8 11.9
- *C. furcellus* Gilbert et Burke, 1912 Forktail snailfish 57.4 58.5
- *C. rastrinus* Gilbert et Burke, 1912 Salmon snailfish 13.8 35.2
- *C. roseofuscus* Gilbert et Burke, 1912 Round snailfish 24.7 23.9
- *Careproctus sp. nov.* 56.6 6.5
- *Elassodiscus obscurus* Pitruk et Fedorov, 1993 Dimdisc snailfish 32.0 22.6
- *E. trembus* Gilbert et Burke, 1912 Okhotsk snailfish 2.5 20.2
- *Liparis ochotensis* Schmidt, 1904 Polypera simushirae (Gilbert et Burke, 1912) 23.1 0.9

* - Scientific and common names are given according to Sheiko & Fedorov 4

Contd…….
species with catches up to 10,000 no/h were registered off the southeastern Kamchatka (area of the “northern” eddy) but largest catches exceeding 100,000 no/h occurred at the northwestern slope of underwater plateau between 48°15′ N and 48°35′ N (Fig. 2A). Atka mackerel was found there often in bottom trawl hauls with large amount of sponges. It should be noted that western slope of underwater plateau serves as feeding grounds for Atka mackerel, where commercial schooling exist in plateau area all the year around.17

Pacific Ocean perch *Sebastes alutus* is only single planktophage fish species permanently dwelling in continental slope waters of the North Pacific.18 It is distributed from the northern Honshu (Myagi Prefecture) along the Kuril and Aleutian Islands to the southern California including the Bering Sea.19 In the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, this species occurred within the whole area but it is most abundant in the southern part of area considered southerly the Fourth Kuril Strait, where its catches exceed 1 000 no/h (Fig. 2B). However, the most dense schoolings Pacific Ocean perch formed at the western slope of underwater plateau and off small banks near the northern edge of plateau with catches, reaching 10,000 no/h and more. Similar to Atka mackerel, Pacific Ocean perch feed mainly on copepods and euphausiids. Dense concentrations of the species occurred in the above area all the year around.17

Prowfish *Zaprora silenus* is rather common species of the North Pacific Ocean that is widely distributed from northern Japan (Hokkaido) along the Kuril and Aleutian Islands and eastern Kamchatka to the North America including the Sea of Okhotsk, Bering Sea and Gulf of Alaska.21 In the study area prowfish occurred from central Paramushir Isl., where its catches did not exceed several specimens per hour, to 48° N with maximum relative abundance, reaching 100-300 no/h, at the western slope of underwater plateau (Fig. 3A). This species often occurred in catches that contained sponges. Prowfish feed on jellyfish-like invertebrates such as Hydrozoa, Ctenophora, Salpa, Appendicularia. The high abundance of prowfish within the plateau area is probably related to enlarged biomass of above jellyfish-like organisms representing the basis of its diet.

**Species, whose whole life cycle occur within plateau waters**

As generally known, snailfishes and broadbanded thornyhead have pelagic larvae and juveniles.22 Pelagic life stages of these species, inhabiting underwater plateau area until settlement, probably occur within the eddy waters that do not allow them to leave underwater plateau area.

Proboscis snailfish *Careproctus simus* is distributed in the North Pacific Ocean from 45° to 60° N from Pacific waters off Japan along Kuril Islands to the Aleutian Islands including the Sea of Okhotsk and Bering Sea.23,24 However, the data on its distribution are limited. In the Pacific waters off the northern Kuril Islands several specimens of proboscis snailfish were caught at the eastern slope of underwater plateau (47°50′-48°40′ N) in the southern part of study area (Fig. 4).

Stout snailfish *Allocareproctus pycnosoma* is distributed in the Pacific waters off Japan, Kuril Islands and eastern Kamchatka.25 In the study area this species occurred from 47°50′ N to 51° N (Fig. 5A) but its maximum catches, reaching 10 no/h, were noted off the Forth Kuril Strait and at the

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<td><em>Bothrocara brunneum</em> (Bean, 1890)</td>
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<td>Whitebar eelpout</td>
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<tr>
<td><em>L. brunniofasciatus</em> Suvorov, 1935</td>
<td>Tawnystripe eelpout</td>
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Pleuronectidae

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<td><em>Atheresthes evermanni</em> Jordan et Starks, 1904</td>
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<td><em>Hippoglossoides elassodon</em> Jordan et Gilbert, 1880</td>
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<td><em>Hippoglossus stenolepis</em> Schmidt, 1904</td>
<td>Pacific halibut</td>
<td>10.6</td>
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<tr>
<td><em>Lepidopsetta polysticta</em> Orr et Matarese, 2000</td>
<td>Northern rock sole</td>
<td>0.8</td>
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<tr>
<td><em>Reinhardtius hippoglossoides matsuurae</em> Jordan et Snyder, 1901</td>
<td>Pacific black halibut</td>
<td>41.8</td>
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* - Scientific and common names are given according to Sheiko & Fedorov4

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Table 1 — Continued…….
Fig. 2 — Spatial distribution and relative abundance categorized by CPUE (no/h trawling) of Atka mackerel *Pleurogrammus monopterygius* (A) and Pacific Ocean perch *Sebastes alutus* (B).

Fig. 3 — Spatial distribution and relative abundance categorized by CPUE (no/h trawling) of prowfish *Zaprora silenus* (A) and Fedorov’s eelpout *Lycenchelys fedorovi* (B).
Fig. 4 — Capture localities of some rare fish species off the underwater plateau: 1 – proboscis snailfish Careproctus simus, 2 – scaled sculpin Archaulus biseriatus, 3 – nutcracker prickleback Bryozoichthys lysimus, 4 – tough eelpout Puzanovia rubra, 5 – fourhorn poacher Hypsagonus quadricornis, 6 – slime flounder Microstomus achne.

Fig. 5 — Spatial distribution and relative abundance categorized by CPUE (no/h trawling) of stout snailfish Allocareproctus pycnosoma (A) and gloved snailfish Palmoliparis beckeri (B).
southern slope of underwater plateau. In the latter area stout snailfish was especially abundant.

Gloved snailfish *Palmoloparis beckeri* was originally described from the Pacific waters off the northern Kuril Islands only recently and is endemic to the study area. All presently known captures of this species were obtained exclusively within the Pacific waters off the northern Kuril Islands southward the Fourth Kuril Strait. In the study area, distribution of gloved snailfish is limited by the Fourth Kuril Strait in the north and southern edge of underwater plateau in the south (47°50′ N). The maximum catches of this species (over 2 no/h trawling) were noted only at the southern slope of underwater plateau (Fig. 5B).

Blacktip snailfish *Careproctus zachirus* was originally described from the Bering Sea off the Aleutian Islands. This species is distributed in the Pacific waters off the northern Kuril Islands and eastern Kamchatka and also in the western Bering Sea off the Aleutian Islands. In the study area, blacktip snailfish occurred from 47°50′ N to 51°30′ N (Fig. 6A) but its largest catches, reaching 20 no/h trawling were registered at the southeastern slope of underwater plateau.

Snailfish *Careproctus cf. cyclocephalus* is one of most abundant liparid species of the study area. Northern boundary of its distribution is limited by the Fourth Kuril Strait (Fig. 6B). The maximum abundance of this species occurred at the eastern slope of underwater plateau, where its catches reached 300-600 no/h. Size of snailfish decreased with increase in depth, i.e. its adults inhabit shallower water as compared to juveniles.

Big-disc snailfish *Squaloliparis dentatus* was originally described from the Sea of Okhotsk off Hokkaido, relatively recently. This species is rather common and widely distributed in the bathyal realm of the Sea of Okhotsk, and also in the Pacific waters off the northern Kuril Islands. In the area under consideration, this species occurred in its southern part from 47°50′ N to the Fourth Kuril Strait (Fig. 7A). The largest catches of big-disc snailfish (up to 200 no/h trawling) were registered at the northern and southern slopes of underwater plateau.

Simushir snailfish *Polypera simushirae* was originally described from the littoral of Simushir Island (central Kurils) and very recently was reported only from above area. Reporting of this species from northern Hokkaido is probably erroneous because later Simushir snailfish were not included in the list of species inhabiting Japanese waters. In the Pacific waters off the northern Kuril Islands, Simushir snailfish is distributed from...
48° N to the central Fourth Kuril Strait (Fig. 7B). The main areas of its inhabitation are slopes of underwater plateau. The maximum abundance of Simushir snailfish was registered at the western slope, where its catches reached 50-100 no/h trawling. Depths of 166-833 m limit vertical distribution of this species in the study area but more than 50% of its relative abundance is distributed at depth < 200 m.

Broadbanded thornyhead *Sebastolobus macrochir* is an endemic species of the northwestern Pacific Ocean being distributed from the Pacific coast of Japan (Sagami Bay) to the central Bering Sea and Aleutian Islands including continental slope areas of the Sea of Okhotsk\textsuperscript{36}. The maps of mean multi-annual distribution of broadbanded thornyhead shows that catches over 50 kg/h (Fig. 8A) were observed along much of the slope with the largest catches (over 500 kg/h trawling) occurring off the underwater plateau area indicating that spawning may occur continuously within the entire investigated area, but more strongly in the southern part. This feature is confirmed by the pattern of distribution of broadbanded thornyhead benthic juveniles (Fig. 8B), which are also caught more frequently in the above area. Size composition of broadbanded thornyheads in the Kuril-Kamchatka region is characterized by a high degree of heterogeneity. The largest fish occurred in three areas: the underwater plateau in the south part of region, a localized section southeast of Onekotan Island, and the southeastern Kamchatka coast near 52° N (Fig. 8C). In each of these areas, mean body length increased from deeper to shallower waters. As it is generally known, thornyheads are egg-layers with internal fertilization\textsuperscript{37} with the eggs being released within gelatinous balloons into the water column. The balloons have positive buoyancy and float to surface where the larvae hatch and further development occurs\textsuperscript{38}. Capture sites of benthic juveniles and the locations of larger catches of post spawners nearly coincide with localized eddies occurring near the southeastern Kamchatka and Paramushir coasts and within the underwater plateau and adjacent banks southeast of Onekotan Island. The co-occurrence of these two groups indicates that early development of the larvae and pelagic juveniles of broadbanded thornyhead might have occurred within the southern eddy until settlement. The locations and depths of capture of predominantly small-sized benthic juveniles may indicate that settlement of broadbanded thornyhead occur within the deeper depths (400-650 m) with larger fish migrating into shallower waters (150 m and deeper).
Species inhabiting among sponges

Some species such as nutcracker prickleback, fourhorn poacher, slime flounder, small sculpins, Atka mackerel, etc. inhabit areas that are covered by dense sponges. Eddy waters probably limit distribution of sponges outside underwater plateau and create favourable environmental conditions for inhabitation of above species only in this area.

Nutcracker prickleback *Bryozoichthys lysimus* being widely distributed in Asian waters occurred from northern Hokkaido along the Kuril Islands and eastern Kamchatka to the Bering Sea including the northern Sea of Japan and Sea of Okhotsk. In the Pacific waters off the northern Kuril Islands, this species was caught only within the underwater plateau area (Fig. 4). Most of individuals were found in the catches from the plateau top at depths < 200 m in association with sponges.

Scaled sculpin *Archaulus biseriatus* was originally described from Petrel Bank, in the southern Bering Sea off Semisopochnoi Island of the Aleutian Archipelago. Since the original description, only a single additional specimen has been recently collected from the central Kuril Archipelago off Simushir Island. During present study, two specimens of scaled sculpin were collected on the top of underwater plateau (Fig. 4) at 48°14.2' N 154°35.1' E (138-140 m depth) and 48°16.5' N 154°32.0' E (100-117 m depth). Specimens have been caught on hard bottom in association with sponges, barnacles, brittle stars, sea urchins, sea cucumbers, bryozoans, ascidians, and primnoid corals.

Sponge sculpin *Thyriscus anoplus* is distributed in the Bering Sea off Aleutian Islands, off the Commander Islands, in the Pacific waters off the northern Kuril Islands and eastern Kamchatka. This species is small mesobenthic sculpin that inhabit mainly lower shelf and upper continental slope within the depth range 104-800 m. In the study area, sponge sculpin is rather common but not abundant representative of ichthyofauna that inhabits areas with complex bottom relief and rocky grounds. Sponge sculpin occurred there from 47°50' N to the Fourth Kuril Strait (only single specimen was caught off the southern tip of Kamchatka peninsula). However, the main area of its inhabitation is placed at slopes (especially western) of underwater plateau (47°50'-48°40' N), where catches of sponge sculpin sometimes reaches over 100 no/h trawling (Fig. 9A).

Roughskin sculpin *Rastrinus scutiger* is distributed in the Bering Sea, off the Commander and Kuril Islands. In the area under consideration, this species occurred only south 50° N (Fig. 9B). Roughskin sculpin catches varied 1-25 no/h trawling. The maximum catch values were registered in both northern and southern parts of area. However, maximum number of captures of species was noted in the area of underwater plateau. In the Pacific waters off the northern Kuril Islands, roughskin sculpin inhabits depth range of 170-480 m but most of its individuals (over 81%) were captured within depth 200 to 300 m.

Spatulate sculpin *Icelus spatula* is rather common species in the Sea of Okhotsk, Bering Sea, arctic basin and the Pacific waters off Kuril Islands and
In the study area, spatulate sculpin was caught only between 47°50′ N and 50°20′ N (Fig. 10A). Its maximum abundance (100-150 no/h trawling) was registered at the top of underwater plateau at depth < 200 m (73% of relative abundance) among numerous sponges. Outside plateau area, captures of spatulate sculpin were incidental. According to the last revision of sculpins, belonging to genus *Hemilepidotus* [45], all the vouched records of adults and benthic juveniles of longfin Irish lord *H. zapus* were recently known only from coastal waters off the Aleutian Islands, although pelagic larvae of this species were found in the eastern Bering Sea [46]. Present study showed that longfin Irish lord is one of most abundant sculpins in the Pacific waters off the northern Kuril Islands. In this area, the species considered occurred only between 47°50′ N and 50°10′ N (Fig. 10B) but its maximum catches (5-10 thousands no/h) are registered at the western slope of underwater plateau (48°10′ N 48°30′ N). *Hemilepidotus zapus* inhabit mainly shelf and continental slope areas with complex relief and rocky grounds that are covered by numerous sponges. Juveniles of this species dwell shallower waters in comparison with adults. Irish lords have pelagic larvae and juveniles [47], which were captured in offshore waters. This allows to assume that development of pelagic young of longfin Irish lord until settlement occurred within the eddy over underwater plateau. After transition from pelagic to benthic stage, juveniles start migrating gradually from upper slope areas to shallower waters.

Scaly-belly sculpin *Icelus perminovi* is distributed from the Pacific coast of Hokkaido to the northern Sea of Okhotsk including waters along Kuril Islands and Kamchatka [48,49]. In the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, this species occurred within the entire study area at depths 200 to 840 m. Scaly-belly sculpin was found mostly in the catches conducted over continental slope areas with complex relief and rocky grounds covered by numerous sponges. Its maximum catches (over 300-400 no/h trawling) were obtained at the eastern slope of underwater plateau (Fig. 11A).

Blacknose sculpin *Icelus canaliculatus* is distributed from Hokkaido coast of the Sea of Okhotsk to the Bering Sea including the Pacific waters off the northern Kuril Islands and eastern Kamchatka [49]. Its distributional features in the study area are very similar to that of scaly-belly sculpin. Blacknose sculpin is occurred there from the southern edge of underwater plateau in the south to 52°N in the north (Fig 11B) but its maximum abundance is noted at the eastern slope of plateau, where catches of species considered constituted 100 to 150 no/h.
Fig. 10 — Spatial distribution and relative abundance categorized by CPUE (no/h trawling) of spatulate sculpin *Icelus spatula* (A) and longfin Irish lord *Hemilepidotus zapus* (B).

Fig. 11 — Spatial distribution and relative abundance categorized by CPUE (no/h trawling) of scaly-belly sculpin *Icelus preminovi* (A) and blacknose sculpin *Icelus canaliculatus* (B).
Fourhorn poacher *Hypsagonus quadricornis* is a rare fish species widely distributed in the North Pacific Ocean from the Japan Sea coast (Niigata Prefecture) to the northern part of the sea and from the Pacific coast of Honshu (Iwate Prefecture) along the Kuril and Aleutian Islands and eastern Kamchatka to Puget Sound including the Sea of Okhotsk, Bering Sea (Gulf of Anadyr in the north and Bristol Bay in the east) and Gulf of Alaska. This species in the study area occurred only within the southern part, mostly at the western section of underwater plateau (Fig. 4) at depths < 200 m at which numerous sponges also occurred.

Slime flounder *Microstomus achne* is a rare flatfish species that inhabit the East China and Yellow Seas, Gulf of Po-Hai, Sea of Japan, Suruga Bay (central Honshu), waters off Sakhalin and Kuril Islands. In the study area, only three specimens of slime flounder were caught at the western slope of underwater plateau (Fig. 4) at depths 116 to 450 m. Some individuals were found in the catches that contained large amount of sponges.

**Species inhabiting corals**

Several species such as spiny eel, tough eelpout, and Fedorov’s eelpout dwell among primnoid corals. Eddy waters may also limit distribution of pelagic larvae of corals in underwater plateau slopes. As a result, eel-like fish species occurred predominantly off underwater plateau area.

Tough eelpout *Puzanovia rubra* is rather common fish species that is widely distributed in the north-western Pacific Ocean from Hokkaido (Cape Erimo) along the Kuril Islands and eastern Kamchatka to the Bering Sea including the Sea of Okhotsk. In the study area, only two specimens were caught at the southern slope of underwater plateau and at the small bank located to the north of this plateau (Fig. 4). According to Fedorov this species lives among corals and feed on soft coral tissues. The life cycles of eelpouts are poorly understood and there is no data on early life stages of this species.

Spiny eel *Notacanthus chemnitzi* is cosmopolitan rare species that is distributed worldwide in deep waters. Single specimens represented captures of spiny eel in the study area usually but most of them (95%) were obtained from its southern part (Fig. 12A). However, spiny eel was caught frequently at the eastern plateau slope, and occurred in association with primnoid corals.

Fedorov’s eelpout *Lycenchelys fedorovi* was originally described from the Pacific waters off the northern Kuril Islands only recently and at present is considered as endemic species of this area. In the

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**Fig. 12 — Capture localities of spiny eel *Notacanthus chemnitzi* (A) and skillfish *Erilepis zonifer* (B).**
Pacific waters off the northern Kuril Islands Fedorov’s eelpout occurred only southerly Fourth Kuril Strait (Fig. 3B). However, this species has the maximum abundance in the northern and southern parts of the eastern plateau slope, where its catch sometimes reaches 10 no/h trawling. This species inhabits relatively deep waters (300 to 650 m), but most of the fishes (70.1% of relative abundance) were distributed within the depth range 450-600 m, the areas being inhabited by primnoid corals. The life cycle of Fedorov’s eelpout is probably associated with these corals because some invertebrates, dwelling on coral branches, were found in its stomach.

Species, for which plateau waters serves as nursery area

Eddy waters also serve as nursery grounds for some species such as shortraker rockfish and darkfin sculpin. They spawn off Paramushir Island and southeastern Kamchatka coast. Only juveniles of these species are caught off underwater plateau area. It is possible that the East Kamchatka current transports their pelagic larvae and juveniles to the south, and then they fall into eddy waters, inhabit this area until settlement and with increase in size start gradual reverse migrations to spawning grounds.

Darkfin sculpin Malacocottus zonurus is distributed in the North Pacific from the northern Japan to the Gulf of Alaska. In the study area, it occurred from the southern tip of underwater plateau in the south to 52° N in the north (Fig. 13A) within the depth range 100-824 m. Catches of species considered varied from several specimens to 1,000-3,000 no/h trawling. In the northern part of investigated area, its abundance was low, catches increased south of the Fourth Kuril Strait, and the maximum abundance was noted at slopes of underwater plateau. Some young bathyal species occupy deeper waters while adults dwell shallower areas. Vertical distributions of different size groups of darkfin sculpin exhibit the same pattern. In the southern part of study area darkfin sculpin was considerably smaller than in the northern areas. Thus, on the shelf and continental slope off Shumshu and Paramushir Islands and southeastern Kamchatka mostly adults with length of 20-35 cm were caught while within underwater plateau area, juveniles with length of 6-20 cm constituted the base of catches. There are several areas, where largest specimens of darkfin sculpin occurred: from the Lopatka Cape
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(southern tip of Kamchatka Peninsula) to 52° N, central Paramushir, off the Fourth Kuril Strait, and local sections off underwater plateau and banks (Fig. 13B). This species has pelagic larvae and juveniles$^{22}$ that were found over deeper depths in offshore waters$^7$. It is possible to assume that early life stages of darkfin sculpin are associated with eddies existing in the study area. Distributional patterns of its different size groups indicates that settlement of pelagic juveniles occur in continental slope areas, followed by gradual migration of growing fish to the shelf.

Shortraker rockfish $Sebastes borealis$ is distributed within the shelf and continental slope waters continuously from the Pacific waters of Honshu (Iwate Prefecture) and southeastern Sakhalin along Hokkaido coast of the Sea of Okhotsk, Pacific side of Kuril Islands, eastern Kamchatka, Aleutian Islands, Gulf of Alaska, and British Columbia to the southern California at 40°46' N including waters of the Bering Sea$^{34}$. The map of the multi-annual spatial distribution (Fig. 14A) shows that shortraker rockfish is most abundant within only two areas (CPUE over 500 kg/h): off southeastern Kamchatka and off the underwater plateau south of Onekotan Isl. At the same time, shortraker rockfish juveniles <15 cm were abundant (Fig. 14B) in the second of the above areas. Smaller shortraker rockfish occurred also, only in the southern part of the investigated area off the underwater plateau (Fig. 14C). Within the same time frame, larger specimens with a mean length >60 cm are caught off Paramushir Island and southeastern Kamchatka to the north of 52° N, suggesting these areas as potential spawning grounds. It is suggested that pelagic larvae of shortraker rockfish produced off the southeastern Kamchatka and Paramushir Island are transported by East Kamchatka current to underwater plateau area, where they fall into the eddy waters and develop in that area until settlement. Then they feed along the plateau slopes and with increase in size, gradually start reverse migrations to the spawning grounds.

Species feeding within the plateau area

Feeding of skilfish, sablefish, Kamchatka flounder, and spectacled sculpin occurs mostly within underwater plateau area. These species do not spawn here (except for spectacled sculpin). Since they consume mainly benthic and benthopelagic fish and large invertebrates, it is presumed that preys of above species in the area considered are more abundant in comparison with waters outside underwater plateau.

Skilfish $Erilepis zonifer$ is distributed from the Pacific coast of Japan and Monterey Bay in the south to the Gulf of Alaska and Aleutian Islands in the north including waters along the Kuril Islands$^{19}$. Information exists on capture of this species in the North Pacific high sea$^{57}$. Large mature specimens were caught mostly on continental slope in coastal waters by trawl and long-line gears while pelagic juveniles occurred mainly in the offshore waters of the eastern North Pacific, where they are often captured during gill net fishery for salmons and nectonic squids. According to Safran & Omori$^{58}$, skilfish juveniles were found among drifting seaweed in offshore waters of Honshu. The captures of large
mature skilfish in the Pacific waters off the northern Kuril Islands increased in the recent years. All the captures of skilfish in the study area (except of single record) were noted at slopes of underwater plateau (Fig. 12B). Most of them occurred in the southern part of plateau. The occurrence of skilfish exclusively within the plateau area cannot be substantiated yet, because this species does not spawn in the area considered and its pelagic juveniles inhabit areas that are very distant from the northern Kuril Islands waters. Increasing number of recent skilfish captures in study area are probably associated with increase in its abundance and extension of its distribution eastward. It may be suggested that skilfish find most favourable conditions for feeding within plateau area, because the adults consume squids and octopi which are abundant in this area.

Kamchatka flounder *Atheresthes evermanni* inhabit mainly Asian waters and distributed from Sendai Bay (Pacific coast of Honshu) and Sea of Japan off Hokkaido in the south to southern Bering Sea in the north including continental slope waters of the most part of the Sea of Okhotsk. Eastern boundary of its distribution is the Gulf of Alaska. Although once Kamchatka flounder was captured off Canadian coast near Vancouver Island. This species in the Pacific waters off the northern Kuril Islands occurred almost within the whole area except for some shelf sections from Paramushir coast to the southern Kamchatka tip. There are two areas with most dense schoolings of Kamchatka flounder that occurred throughout the year (Fig. 15A): off the southeastern Kamchatka coast (area of “northern” eddy), central part of the Fourth Kuril Strait, and off underwater plateau. Maximum catches (over 100 no/h) were registered south of Fourth Kuril Strait but largest catches, reaching 250 no/h, were obtained at slopes of underwater plateau.

Sablefish *Anoplopoma fimbria* inhabit continental slope waters from the Pacific coast of Hokkaido (Volcanic Bay) to the southern California including the Bering Sea and Sea of Okhotsk. There are two areas in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, where sablefish has maximum abundance (Fig. 15B): the southeastern Kamchatka coast from Lopatka Cape (southern tip of peninsula) to 51°30’ N (“northern” eddy area) and southeastern slope of underwater plateau. In the northern area maximum sablefish catches were 50-100 no/h trawling while in the southern one respective values were 100 to 150 no/h. Sablefish is most abundant off the North America coast that is considered as its breeding area. Some authors reported that sablefish, inhabiting Asian waters, migrate there from the eastern North Pacific and does not spawn in this area. Therefore it is difficult to associate existence enlarged abundance of sablefish within eddies waters, with its breeding patterns. Since sablefish in the study area consume mostly benthic and bentho-pelagic invertebrates and fish, the above distribution pattern may be related only to feeding factor, i.e. probable enlarged biomass of its preys occurred in eddy areas.

Spectacled sculpin *Triglops scepticus* is common and rather abundant, widely distributed in the North Pacific Ocean from Toyama Bay (central Honshu)
along Kuril and Aleutian Islands and eastern Kamchatka to the Gulf of Alaska including waters of the Sea of Japan, Sea of Okhotsk, and Bering Sea. There are two areas in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, where spectacled sculpin has maximum abundance (Fig. 15C): the southeastern Kamchatka coast from Lopatka Cape to 51°30’ N (“northern” eddy area) and top and slopes of underwater plateau, especially in its northern part. In the northern area maximum catches of spectacled sculpin were 500-1,000 no/h trawling while in the underwater plateau area some catches reached 1,000 to 3,500 no/h. This species is typically bentophagic sculpin, consuming mainly benthic invertebrates. However, sometimes off underwater plateau mesopelagic fishes were found in its stomach.

Conclusion

Eddies may affect spatial distribution and some life history patterns of various groundfish species, having different life cycles. Eddies may limit distribution of species with pelagic eggs, larvae, and fry (such as snailfishes, sculpins, flounders, and broadbanded thornyhead), which until settlement inhabit eddy waters that do not allow them to leave underwater plateau area. Among these fishes only broadbanded thornyhead has commercial importance. Localization of dense schools of this species within eddy waters supports commercial fishery along underwater plateau slopes throughout the year.

Some species inhabit areas that are covered by dense sponges (nutcracker pindleback, fourhorn poacher, slime flounder, small sculpins) or corals (spiny eel, eelpouts). Eddy waters may limit distribution of sponges and corals outside underwater plateau and create favourable environmental conditions for these species. Eddies are able to concentrate plankton that results in increasing of its biomass. Therefore feeding of some plankton-feeders including commercially important Atka mackerel and Pacific Ocean perch within eddy waters at underwater plateau occurred throughout the year that supports commercial fishery in this area. Eddy waters serve as nursery grounds for some species as well (shortraker rockfish and darkfin sculpin). They spawn off Paramushir Island and southeastern Kamchatka coast. East Kamchatka current transports their pelagic larvae and juveniles to the southern eddy, where they inhabit until settlement and with increasing in size perform gradual reverse migrations to spawning grounds. Feeding of skiffish, sablefish, and Kamchatka flounder occur within underwater plateau area, where they do not spawn. High abundance of these species feeding on demersal fish and large invertebrates may be explained by enlarged biomass of preys within plateau in comparison with outside waters.

Acknowledgement

Author expresses deep gratitude to all his colleagues from Russian Federal Institute (VNIRO), Sakhalin (SakhNIRIO), and Kamchatka (KamchatNIRO) Institutes of Fisheries & Oceanography, Institute of Marine Biology of Far East Branch of the Russian Academy of Sciences (IMB FEB RAS), Zoological Institute of the Russian Academy of Sciences (ZIN RAS), and Kamchatka Branch of Pacific Institute of Geography of the Russian Academy of Sciences (KBPIG FEB RAS), who participated in numerous research cruises conducted aboard Japanese trawlers within the frame of joint scientific program. Special thanks to Dr. D. Pitruk (IMB FEB RAS), Dr. V. Polutov (KamchatNIRO), Dr. S. Leontiev (VNIRO), Dr. I. Biryukov, and Dr. O. Nemchinov (both from SakhNIRO), who assisted me in this study, and to Dr. A. Balanov (IMB FEB RAS) and Dr. B. Sheiko (ZIN RAS) for identification of some species.

References

14 Dogel V A, Zoology of invertebrates, (Vysshaya Shkola, Moscow, Russia) 1975, pp. 560 (In Russian).
Orlov : Impact of eddies on spatial distributions of groundfishes


45 Peden A E, A systematic revision of the hemilepidotinae fishes (Cottidae), Syesis, 11 (1979) 11-49.


