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RESEARCH ARTICLE

Smooth lumpsucker *Aptocyclus ventricosus* in the northwestern Sea of Japan: distribution and some life history traits

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Abstract. This paper is focused on horizontal, vertical, and temperature-dependent distributions, size composition of bottom and mid-water trawl catches, and biomass estimations of smooth lumpsucker *Aptocyclus ventricosus* (Pallas) (Cyclopteridae) within the Russian Exclusive Economic Zone (EEZ) of the northwestern Sea of Japan. This species is distributed very widely throughout the study area inhabiting both near-bottom layers and water column. It is less abundant in small bays and in the northern Tatar Strait (north to 50°N). Despite wide bathymetric (0 to 940 m) and temperature (-1.1 to +12.2°C) ranges this species occurred mainly within the lower mesopelagic zone of 400-800 m depths and cold temperatures of -0.5-1°C. In the near-bottom layer catches of smooth lumpsucker were represented by fish with TL 5-45 cm (mean 28.1 cm, dominant lengths 29-37 cm) while in water column its TL varied 4 to 41 cm with mean 17.9 cm, most abundant were fish with TL 8-15 and 24-31 cm; the difference is associated with specific life history aspects of the species considered. Recent increase of smooth lumpsucker biomass in the study area was observed with estimated value of 3000 t in the northern Primorye.

Keywords: smooth lumpsucker *Aptocyclus ventricosus*, Sea of Japan, spatial and vertical distributions, water temperature, size composition, biomass

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Introduction

Smooth lumpsucker *Aptocyclus ventricosus* (Pallas) (Cyclopteridae, Scorpaeniformes, Actinopterygii) is distributed widely in the North Pacific from coastal waters to high seas, from sea surface to deep-water layers, including seamounts (Hughes 1981, Mecklenburg et al. 2002). Its range in the Sea of Japan covers the entire area from Busan on the continental part and Wakasa Bay (central part of Honshu Island, Japan) in the south to the northern Tatar Strait in the north (Lindberg and Krasyukova 1987, Amaoka et al. 1995, Nakabo 2002).

In many areas of its habitation, *A. ventricosus* is a common or abundant species (Fedorov and Parin 1998, Sheiko and Fedorov 2000, Chereshnev et al. 2000, Fedorov et al. 2003, Bailey 2011) playing a considerable role in fish communities (Il'inskii and Radchenko 1992). It is rather important in trophic chains, having been eaten by Steller's sea lions *Eumetopias jubatus*, fur seals and seals (Odobenidae, Otariidae, Phocidae), sperm whales *Physeter macrocephalus*, sea otters *Enhydra lutris*, bald eagles *Haliaeetus leucocephalus*, and Steller's sea eagles *Haliaeetus pelagicus* (Vinogradov 1950, Berzin 1959, Hart 1973, Kato 1982, Anthony et al. 1999, 2008, Utekhina et al. 2000, Watt et al. 2000, Reisewitz et al. 2006, Zeppelin and Ream 2006, McKenzie and Wynne 2008, Sinclair et al. 2008, Blokhin 2010). It is also occasionally found in stomachs of some predatory fish on the continental slope (Yang and Livingston 1988, Orlov 1997), for instance, Greenland halibut *Reinhardtius hippoglossoides* (Walbaum) and sablefish *Anoplopoma fimbria* (Pallas). On the other hand, smooth lumsucker consume predominantly coelenterates (Yoshida and Yamaguchi 1985, Arai 1988, Ates 1988). This species is also considered prospective for maintenance in public aquariums (Orlov et al. 2015).

It might be noted that smooth lumpsucker males die after completing a cycle of guarding their nests (Vinogradov 1950). They became an easy prey of marine birds and their dead bodies are involved into biogenic exchange increasing contents of organic matter in coastal waters. Thus smooth lumpsucker represents important link of trophic webs transporting organic matter from the lower trophic levels (gelatinous plankton) to highest ones (birds, marine mammals and humans).

Smooth lumpsucker during its life cycle inhabits various biotopes, including both pelagic and near-bottom environments, from sea surface and tidal areas to high sea and oceanic depths. These various biotopes are inhabited by the variety of different species co-occurring with smooth lumpsucker in catches. The data on species that are accompanied by smooth lumpsucker in catches are scarce and scattered in published literature. Meanwhile, such data are important for better understanding of the life cycle and the position of species considered in different communities.

Distribution of smooth lumpsucker was described in details for the Bering Sea (Yoshida and Yamaguchi 1985, Il'insky and Radchenko 1992) and Pacific waters of the northern Kuril Islands and southeastern Kamchatka (Orlov and Tokranov 2008). As for the Sea of Japan, some data on distribution and catch rates of smooth lumpsucker within in the Russian EEZ might be obtained from several recent publications (Shuntov and Bocharov 2004a, 2004b, 2014a, 2014b). Recently, the data on catches of the species under consideration in waters around Hokkaido were also published (Yoshida and Mihara 2015). However, above-mentioned publications are in Russian and Japanese respectively and thus are hardly accessible for readers worldwide.

Despite its rather high abundance, this species has no commercial importance in Russian fisheries and is taken only in trawls as by-catch (Fedorov and Parin 1998, Chereshnev et al. 2001, Novikov et al. 2002, Fedorov et al. 2003). However in Japan, *A. ventricosus* has some commercial value. In the 1960s, in waters off southern Hokkaido, its annual catch comprised from 2 to 40 t; however, market prices were low (Kyushin 1975). In recent years (2001-2005) annual catch in waters off Hokkaido varied between 210 and 587 t with average catch of 328 t (Yoshida and Mihara 2015). Nevertheless, the life history of smooth lumpsucker of the Sea of Japan is poorly understood. Published papers are dealing mostly with its taxonomy and zoogeography (Ueno 1970, Lindberg and Krasyukova 1987) or with reproductive biology and early ontogeny (Homma 1957, Kobayashi 1962, Kyushin 1975, Kim et al. 1987, Novikov et al. 2002, Sokolovsky et al. 2011, Zhukova et al. 2018).

The main objective of the current research is to analyze horizontal and vertical distributions of smooth lumpsucker within the Russian waters of the Sea of Japan depending on season and water temperature, to consider size and quantitative characteristics of the species and to evaluate dynamics of its biomass for better understanding of species ecology and some specific life history traits.

Material and methods

Data used in this research came from 159 trawl surveys conducted in the northwestern Sea of Japan, 1978-2014 (Fig. 1). The total number of hauls was 16232 (including 2392 mid-water trawls), with smooth lumpsucker registered in 799 hauls. Between calendar seasons the data of the catch were distributed as follows: bottom trawl hauls – 45 in winter, 431 in spring, 85 in summer and 116 in autumn; mid-water trawl hauls – 39 in winter, 40 in spring, 14 in summer and 29 in autumn. Bottom trawl hauls were conducted within the depth range 2 to 940 m, while mid-water trawls covered depths from the sea surface down to 750 m.

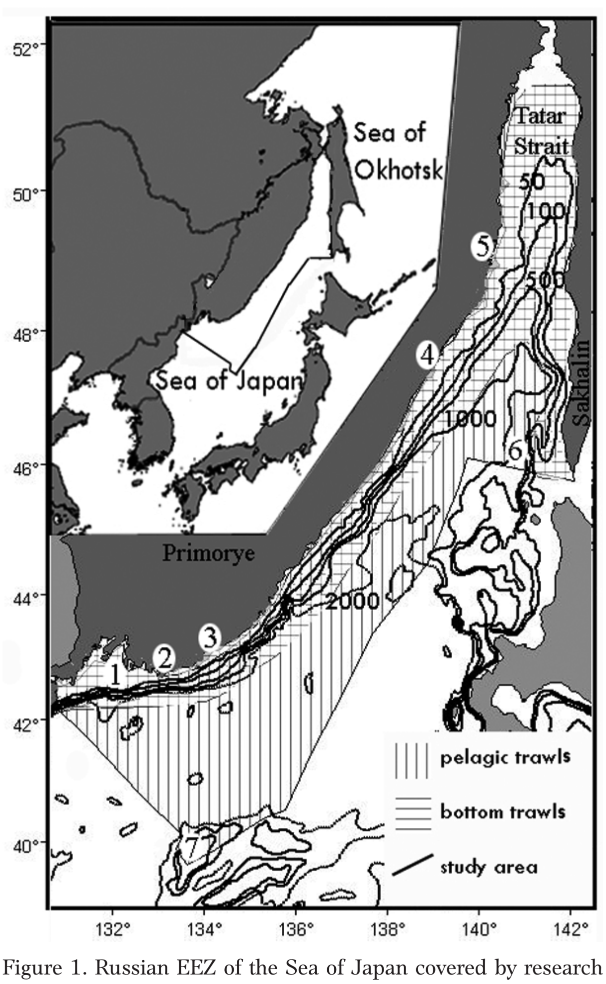

Figure 1. Russian EEZ of the Sea of Japan covered by research trawl surveys; 1 – Peter the Great Bay, 2 – Cape Povorotny, 3 – Preobrazheniye Bay, 4 – Cape Zolotoy, 5 – Sovetskaya Gavan' Bay, 7 – Kita-Yamato Bank; 50, 100, 500, 1000, and 2000 – isobaths.

During trawl surveys, various types of vessels and gears were used. Vessels were represented by trawlers, whose length varied 21.9 to 103.7 m, width – 6.0 to 16.0 m, displacement tonnage – 104 to 5720 t, main engine power – 1 × 110 to 2 × 2580 Kw. The main vessel used in recent years (RV "Bukhoro") is 103.7 m long and 8.8 m wide with displacement tonnage 549 t and main engine power 1 × 590 Kw.

Bottom trawls used during the surveys had vertical and horizontal openings 5-8 and 13-17 m respectively, those dimensions of mid-water trawls were 10-30 and 30-70 m. Mesh size in both types of gears varied 30 to 50 mm, codend was equipped with a small-size mesh (10 mm) insert panel.

To standardize the survey data and to neutralize the impact of trawling speed, the type of vessel and the different trawl characteristics, all catches were recalculated to standard CPUE (kg per km^2) that represents area surveyed (S) multiplied by an average catch per hour (n). The data from mid-water trawl hauls were used for map charting in the pelagic layer only since mid-water trawls had relatively high vertical opening. For biomass estimations and the analysis of vertical distribution of smooth lumpsucker we used the data from bottom trawl hauls only.

Biomass of smooth lumpsucker was estimated based on results of bottom trawl surveys only (as most representative) with the use of square methods by formula:

$$B = \frac{S \times n}{q \times k}, \text{ where}$$

B – biomass (t), S –area surveyed (m^2), n – average catch per hour (kg per h), q – mean area fished per hour (m^2 per h), k– coefficient of catchability.

Value of q was estimated by formula:

$$q = v + h, \text{ where}$$

v – trawling speed (m per h), h – horizontal opening of trawl (m) that was considered equal to 0.6 of the length of upper headline for each trawl. The total biomass was calculated as the sum of biomass estimated for each standard depth stratum (0-20, 21-50, 51-100, 101-200, 201-300, 301-400, 401-500, 501-700, and 701-1000 m), using catchability

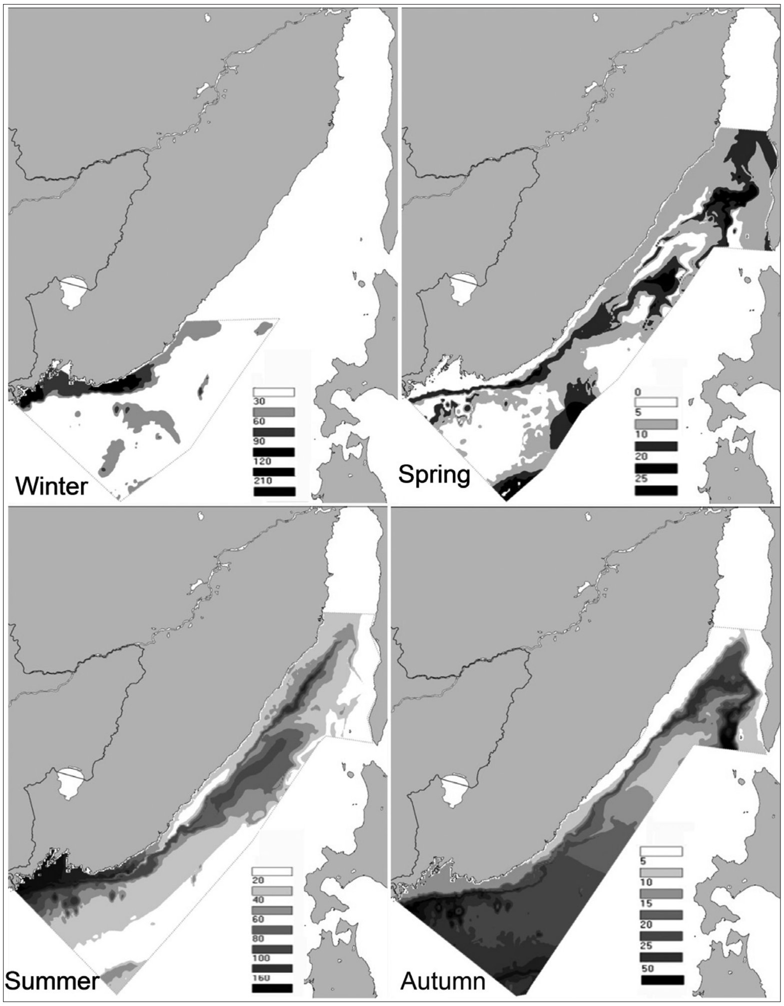

Figure 2. Spatial distribution (kg per km^2) of smooth lumpsucker (*Aptocyclus ventricosus*) pelagic trawl catches in the northwestern Sea of Japan, 1981-2012.

coefficient (*k*) of 0.5 (Shuntov and Bocharov 2014a, 2014b).

Spatial distribution maps were drawn using Chartmaster 4.1 software (©VNIRO, Moscow, 2003-2008; ©Polyakov A.V., Novocherkassk, 2003-2008).

Total length (TL, cm) was measured for 865 specimens (including 108 ind. from mid-water and 757 ind. from bottom trawl catches); body weight (BW, g) was determined in 180 fish. The fish body weight was estimated with water swallowed that is typical for some lumpsuckers of the family Cyclopteridae, e.g. smooth lumpsucker *Aptocyclus ventricosus* and *Eumicrotremus soldatovi* Popov (Orlov 1994, Orlov and Tokranov 2008).

Water temperature was measured using SBE 19plus SeaCAT Profiler CTD (Sea-Bird Scientific, USA) after most of bottom trawl station from the sea surface to the bottom in automatic mode. There were 572 measurements of water temperature in total with 365 measurements in spring, 94 in summer, 110 in autumn and 3 in winter. Bottom temperatures were used to characterize seasonal patterns of smooth lumpsucker distribution depending on water temperature.

The analysis of the composition of species co-occurring with smooth lumpsucker in catches was done based on the frequency of occurrence. During the trawl surveys the whole catch was analysed. It was sorted by species, then individuals were counted

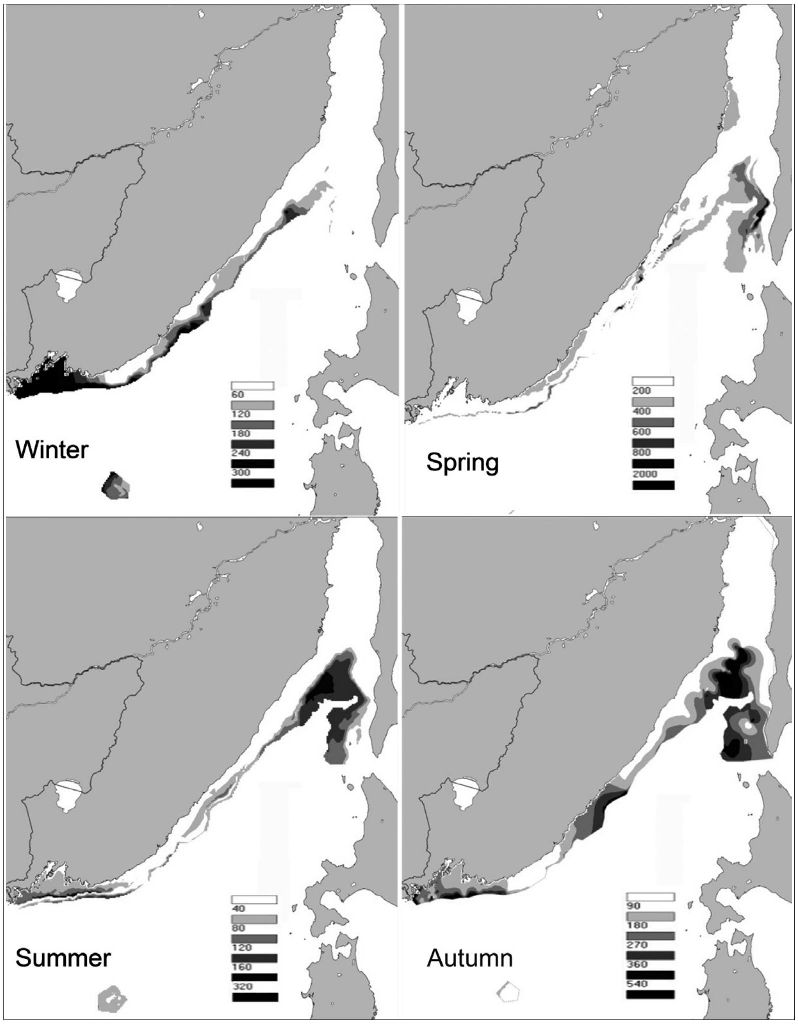

Figure 3. Spatial distribution (kg per km^2) of smooth lumpsucker (*Aptocyclus ventricosus*) bottom trawl catches in the northwestern Sea of Japan, 1978-2014.

and weighed. The frequency of occurrence (FO, %) for each species was calculated as a percentage of trawls in which this species was recorded.

Results

Spatial distribution

The horizontal distribution of smooth lumpsucker based on the data from mid-water trawl hauls is shown for different seasons in Fig. 2, and it covered almost the entire Russian Exclusive Economic Zone (EEZ), with an exception of northern Tatar Strait. In the water column, during spring (March-May), density of smooth lumpsucker aggregations was rather low with maximum about 25 kg per km^2. Such a density occurred in the southern part of Tatar Strait, off central Primorye and in the southern part of Russian EEZ along the border of Japanese waters. In summer (June-August), density of lumpsucker aggregations increased up to 160 kg per km^2 with highest CPUE in the southern part of Russian EEZ, in the Peter the Great Bay. In autumn (September-November), density of aggregations again decreased with maximum CPUE values down to 50 kg per km^2. Most dense schools were observed off the Peter the Great Bay, off the southwestern Sakhalin

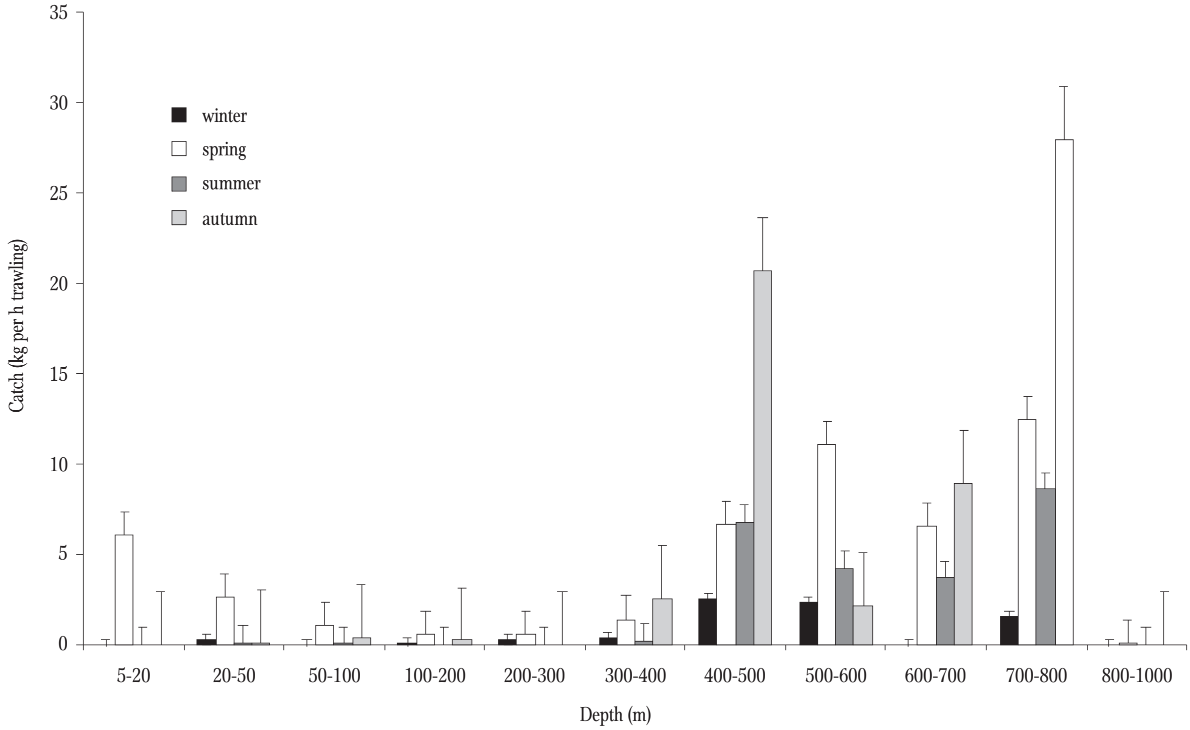

Figure 4. Bathymetric distributions of smooth lumpsucker (*Aptocyclus ventricosus*) catches in the northwestern Sea of Japan in different seasons (bars are means + standard errors), 1982-2014.

and in southeastern corner of Russian EEZ. In winter (December-February), smooth lumpsucker inhabited southern part of the Russian EEZ only with maximum concentrations up to 210 kg per km^2. Such dense schools occurred in the western part of the Peter the Great Bay and in the southern Primorye from Cape Povorotny to Preobrazheniye Bay.

Spring horizontal distribution of lumpsucker catches from bottom trawls (Fig. 3) was very dense (up to 2000 kg per km^2) but occurred off southwestern Sakhalin only. In summer, the area of occurrence in southern part of Tatar Strait considerably extended but density of aggregations decreased down to 320 kg per km^2. In autumn period, density of schoolings slightly increased (up to 520 kg per km^2) with maximum concentrations still occurred in the southern part of Tatar Strait and off the Peter the Great Bay. Winter concentrations of smooth lumpsucker near the bottom were similar in value to those in summer and occurred mostly in the Peter the Great Bay. In the southernmost part of the Russian EEZ, on the Kita-Yamato Bank, smooth lumpsucker was accounted in catches all year round. Less frequently this species occurred in catches in this area during winter and spring.

Both bottom and mid-water trawl hauls revealed similar seasonal patterns of spatial distribution of smooth lumpsucker within the Russian EEZ. In spring it is widely distributed in this area and forms dense concentrations in the southern part of Tatar Strait, off southwestern Sakhalin only. In summer and autumn periods both near the bottom and in water column, species considered concentrates mostly in the southern part of Tatar Strait and partly in the Peter the Great Bay. In winter time, it occurs predominantly in the southern part of the Russian EEZ with maximum concentrations in the southern Primorye and the Peter the Great Bay.

Depth distribution

The smooth lumpsucker in the Sea of Japan inhabited the entire depth range surveyed (0 to 940 m) (Fig. 4). Off the Kita-Yamato Bank, capture depth of smooth lumpsucker varied from 490 to 740 m (mean

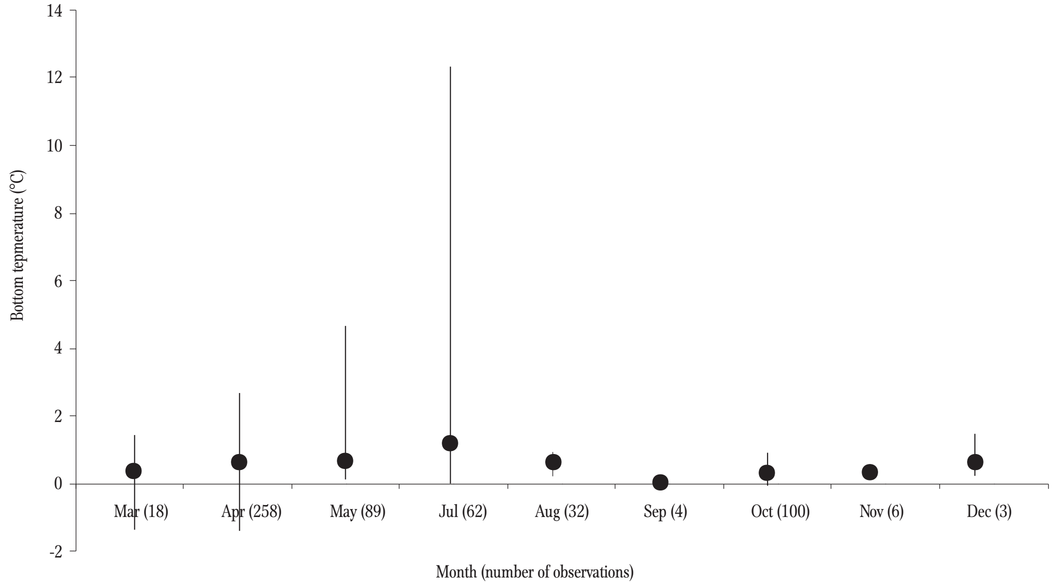

Figure 5. Monthly distributions of smooth lumpsucker (*Aptocyclus ventricosus*) in the northwestern Sea of Japan depending on the bottom temperature, 2004-2014 (dots are means, bars are variations).

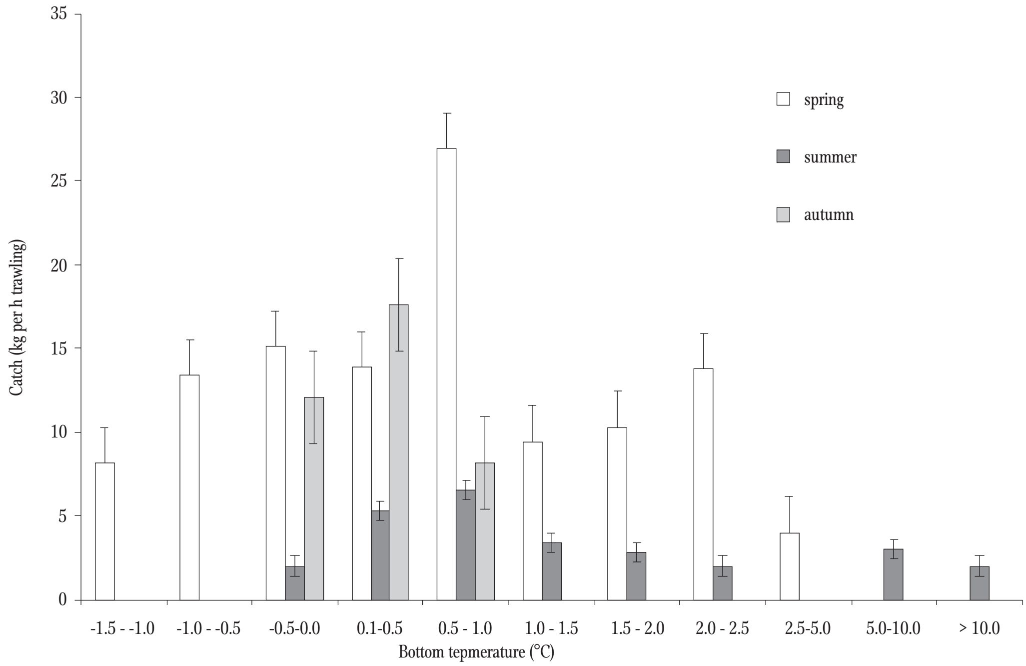

Figure 6. Distribution of smooth lumpsucker (*Aptocyclus ventricosus*) bottom catches in the northwestern Sea of Japan depending on water temperature in different seasons, 2004-2014 (bars are means + standard errors).

536 m). However, during the most part of the year it was observed between 400 and 800 m. As a rule, smooth lumpsucker prefers several noncontiguous depths layers, where its catches are largest. In summer and autumn, these depths are 400-500 and 700-800 m, in spring 5-20, 500-600, and 700-800 m. In winter, its catches are not high at any depths.

Temperature conditions

Smooth lumpsucker occupies waters with wide temperature range from -1.1°C to 12.2°C that depends on the season of study. Maximum value of mean bottom temperature was registered in July (1.16°C) while minimum one (-1.1°C) was observed in March

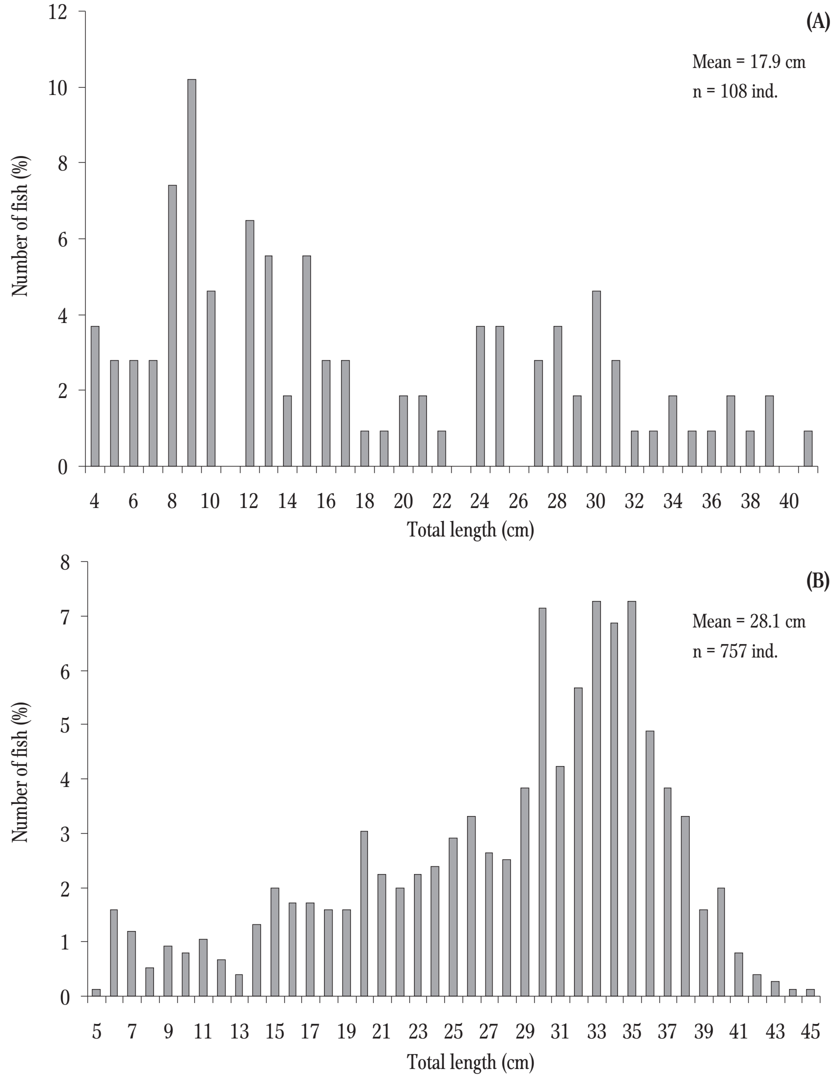

Figure 7. Size composition of smooth lumpsucker (*Aptocyclus ventricosus*) in the northwestern Sea of Japan in mid-water (A), 1984-1997 and bottom (B), 2004-2014 trawl catches.

and April (Fig. 5). In March and April, smooth lumpsucker occurred at negative temperatures. Widest range of bottom temperatures was observed in July. In this period smooth lumpsucker was distributed within broad depth range from 25-30 m with temperatures more than 10°C to over 600 m where temperatures were about 0°C.

Smooth lumpsucker exhibits some seasonal changes in temperature-depending distribution (Fig. 6). In spring, it was observed from 1.5 to 5.0°C with highest catches (9.4-26.9 ind. h^{-1}) within temperature range -1.0-1.0°C. In summer, it occupied warmer temperatures within the range from -0.5 to over 10.0°C with highest catches (3.4-6.5 ind. h^{-1}) from 0.1 to 1.5°C. Autumn distribution was characterized by very narrow range (-0.5-1.0°C) with catches varied 8.2-17.6 ind. h^{-1}. However, during the most part of the year maximum catches of smooth lumpsucker were observed at a temperature range from -0.5 to 1.0°C.

Size composition

Total length (TL) of smooth lumpsucker in catches varied from 4 to 45 cm (Fig. 7). Catches of mid-water trawl were dominated by two modal size classes

(8-15 cm, 45% and 24-31 cm, 25%) with mean total length of 17.9 cm. Mean TL in bottom trawl catches made up to 28.1 cm while specimens with TL 29 to 37 cm were most abundant (47%). Relation between length and body weight of smooth lumpsucker in the Sea of Japan was described by the following equation:

$$W = 0.14 \times TL^{2.7306}$$

where W is body weight in grams and TL is total length in centimeters (Fig. 8).

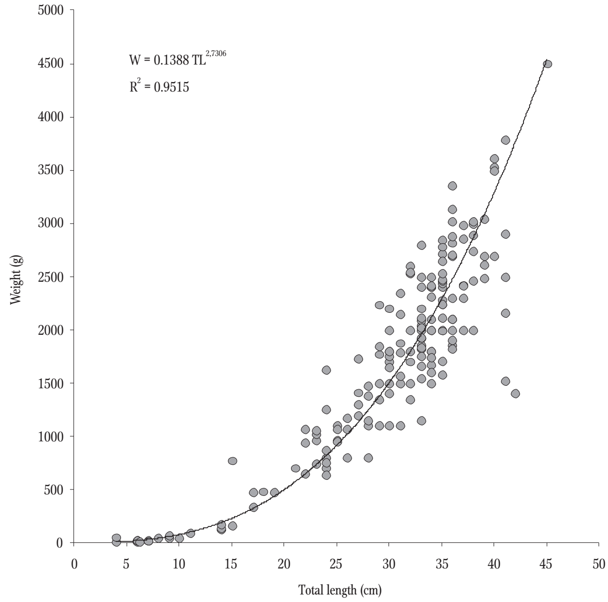

Figure 8. Relationship between total length and body weight of smooth lumpsucker (*Aptocyclus ventricosus*) in the northwestern Sea of Japan, 1982-2014.

Co-occurring species

Total species composition of bottom trawls with catches of smooth lumpsucker was indicative for the entire bathymetric range preferred by this species. The most frequently co-occurring species were scale-eye plaice *Acanthopsetta nadeshnyi* Schmidt with frequency of occurrence 70%, darkfin sculpin *Malacocottus zonurus* Bean – 59%, and Commander squid *Berryteuthis magister* – 51%. The following species also co-occurred frequently with smooth lumpsucker: northern shrimp *Pandalus borealis* – 49%, Korean flounder *Glyptocephalus stelleri* (Schmidt) – 47%, and Tanner crab *Chionoecetes opilio* – 40%.

In mid-water trawls smooth lumpsucker was more frequently caught together with walleye pollock *Theragra chalcogramma* Pallas – 82%, Japanese sardine *Sardinops melanostictus* (Jenyns) – 80%, Japanese flying squid *Todarodes pacificus* – 55%, arabesque greenling *Pleurogrammus azonus* Jordan & Metz – 43%, pink salmon *Oncorhynchus gorbuscha* (Walbaum) – 38%, Pacific herring *Clupea pallasii* Val. – 27%, and Commander squid – 20%. Frequency of occurrence of other species in mid-water trawl catches was less than 20%.

Demography

Annual estimations of smooth lumpsucker biomass for different areas of the northwestern Sea of Japan varied considerably. In the Peter the Great Bay, an increasing trend was observed, with maximum biomass values in the period 2009 to 2010, followed by biomass decline (Table 1). Off the continental part of the Tatar Strait, maximum values of smooth lumpsucker biomass were observed in 2011 to 2012, followed by subsequent sharp decline. The species occurred in the northern Primorye regularly but its biomass reached maximum values only recently (2013-2014).

Discussion

Spatial distribution

Spatial distribution of smooth lumpsucker in the Sea of Japan prior to our research was poorly understood. Its distribution is determined, to a great extent, by seasonal changes in water temperature that, in its turn, impact physiological condition of fish, i.e. relating to spawning, feeding, and wintering that are associated with inshore and offshore migrations.

As our data showed (Figs. 2 and 3), in winter and spring periods, smooth lumpsucker is distributed mostly in coastal waters that most likely associated

Table 1
Biomass (t) of smooth lumpsucker (*Aptocyclus ventricosus*) in various areas of the northwestern Sea of Japan (number of hauls is shown in brackets). Symbol «-» means that there was no research survey in particular year, 0.0 means that smooth lumpsucker lacked in catches, PGB = Peter the Great Bay (11 thousands km^2), NP = northern Primorye (33 thousands km^2), TS = continental part of the Tatar Strait (30 thousands km^2)

	Year													
Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PGB	0.0 (128)	0.0 (124)	21.1 (122)	0.0 (131)	0.0 (148)	0.0 (140)	0.0 (141)	51.2 (124)	160.9 (304)	200.7 (145)	39.4 (101)	0.0 (115)	87.2 (121)	44.0 (123)
NP	-	191.6 (143)	-	162.7 (165)	147.2 (154)	-	152.3 (180)	-	487.8 (178)	382.5 (161)	801.9 (172)	909.1 (166)	3058.7 (165)	2114.2 (167)
TS	-	-	-	-	-	-	-	-	0.0 (136)	0.0 (156)	552.9 (146)	688.6 (143)	0.0 (114)	130.9 (139)
Total	0.0 (128)	191.6 (267)	21.1 (122)	162.7 (296)	147.2 (302)	0.0 (140)	152.3 (321)	51.2 (124)	648.7 (618)	583.2 (462)	1394.2 (419)	1597.7 (424)	3145.9 (400)	2289.1 (429)

with inshore spawning. Spawning season of smooth lumpsucker, due to its lengthiness in time, are quite similar for various parts of species' range: February to May in the Pacific waters of the northern Kuril Islands and Kamchatka (Orlov and Tokranov 2008), December to June in the western Bering Sea (Il'insky and Radchenko 1992), February to May in the northwestern Sea of Japan and Hokkaido (Kyushin 1975, Novikov et al. 2002). Seasonal catch dynamics may provide additional information about duration of spawning period. Thus, maximum catches in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka (Orlov and Tokranov 2008) occur in February-April, in Korean waters of the Sea of Japan and off Hokkaido (Lee et al. 2010, Yoshida and Mihara 2015) in February-March.

Published data on spatial distribution of smooth lumpsucker in other part of its range is rather scarce (Yoshida and Yamaguchi 1985, Orlov and Tokranov 2008, Romain et al. 2012). However, seasonal patterns of spatial distribution of the species in various areas are quite similar. In winter and spring its main concentrations occur in coastal waters that is associated with spawning period, while in summer and autumn it is widely distributed throughout its range, mostly inhabiting areas distant from coasts. During the feeding period, smooth lumpsucker inhabits mostly pelagic environment and this is probably main reason why bottom trawl catches notably decrease in summer and autumn.

Depth distribution

The species ecology is characterized by a wide range of depth distribution. This species inhabits both pelagic and near-bottom water layers from the sea surface down to 1700 m (Allen and Smith 1988, Novikov et al. 2002, Fedorov et al. 2003). It should be noted that in the Sea of Japan, this species prefers deepest depths as compared to other more northern areas. In the western Bering Sea, smooth lumpsucker is most frequently observed at depths 100 to 200 m (Il'insky and Radchenko 1992), in the central Bering Sea (Donut Hole) – between 50 and 260 m (Glubokov and Popov 2004), in the southeastern Bering Sea – < 250 m (Sinclair and Stabeno 2002), in the eastern Bering Sea and northeastern Pacific – at depths 50 to 100 m (Allen and Smith 1988), in the Pacific off the northern Kuril Islands and Kamchatka – at 200-400 m (Orlov and Tokranov 2008), in the Sea of Okhotsk – between 400 and 600 m (Shuntov 1965). During the eastern Bering Sea continental slope bottom trawl survey, this species occurred much deeper – 216 to 1172 m with mean depth 712 m (Hoff 2016).

Temperature conditions

In the Pacific waters off the northern Kuril Islands and southwestern Kamchatka the species prefers rather narrow range of water temperatures from 0.6 to 2.5°C (Orlov and Tokranov 2008) that is associated with its preference of deep waters where temperatures do not vary significantly. In coastal waters, temperatures in areas of smooth lumpsucker habitation vary seasonally and at a greater scale. Thus in waters of southern Hokkaido near Shikabe, temperature at the sea bottom at depths about 10 m is about 3-5°C in February, about 4-6°C in April (smooth lumpsucker spawning period is between early February and early April), and gradually rises to 6-7°C in early May (the hatching season in nature is from early April to early May) (Kyushin 1975). The maximum known temperature for Primorye waters at which smooth lumpsucker was recorded previously was 8.4°C (Orlov and Tokranov 2008). We recorded some specimens in July at temperatures over 10°C that lie within known summer temperature range for this species: it was previously recorded at temperature 13°C in waters off southeastern Kamchatka (Vinogradov 1950) and at 14-15°C off Hokkaido (Kyushin 1975).

Size composition

Larger sizes of smooth lumpsucker in bottom trawls in shelf waters, as compared to fish collected in mid-water trawls, were also observed in other areas of the species' range (Il'insky and Radchenko 1992, Glubokov and Popov 2004). In general, size compositions of smooth lumpsucker in various parts of its distribution range have a similar pattern: its length somewhat increases southward. Thus, mean lengths were 26.2 cm in pelagic layer above the shelf zone of the western Bering Sea (Il'insky and Radchenko 1992) and 28.9 cm in the Pacific off the northern Kuril Islands and southeastern Kamchatka (Orlov and Tokranov 2008). Demersal gill net catches off southern Hokkaido during smooth lumpsucker spawning period consist of females with mean total length 35.1 cm (range 31 to 39 cm) and males with mean total length 30.3 cm (range 26 to 36 cm) (Kyushin 1975).

Low number of small-sized fish in our bottom trawls might be explained by the fact that juvenile smooth lumpsuckers inhabit mostly pelagic waters. At the same time, size composition of smooth lumpsucker in mid-water catches resembles that from the Aleutian Basin of the Bering Sea (Yoshida and Yamaguchi 1985, Glubokov and Popov 2004), where fishes of two size classes (9-16 cm and 17-36 cm) were also most abundant. Larger specimens greater than 17 cm long have well developed gonads that characterize their condition as sexually mature. This observation allowed authors to suggest that specimens attained *TL* at least 17 cm will migrate to coastal waters in the following year for spawning. We assume that this conclusion might be extrapolated to size composition of our catches as well.

Relationships between smooth lumpsucker total length and body weight for more northern areas look somewhat differently (Il'insky and Radchenko 1992, Orlov and Tokranov 2008) that might be associated with different amount in fish weight of swallowed water that cannot be tested statistically. Small-sized smooth lumpsuckers from the Sea of Japan seem to have lesser body weight as compared with fish of the same length from other areas. However, linear growth is associated with increase in body weight that in large smooth lumpsuckers from the study area seems to be higher as compared with fish from Pacific waters off Kuril Islands and Kamchatka and quite similar to fish from the Bering Sea (Il'insky and Radchenko 1992, Orlov and Tokranov 2008).

Co-occurring species

Smooth lumpsucker is widely distributed in the North Pacific from subtropical and temperate to boreal and subarctic waters. This results in different composition of co-occurring species in various parts of species' range. Data on composition of species co-occurring with smooth lumpsucker are mostly available from mid-water surveys. Pelagic catches conducted in surface waters off Hokkaido and Kuril Islands were mainly composed by Japanese sardine, Japanese anchovy *Engraulis japonicus* Temminck & Schlegel, Pacific saury *Cololabis saira* (Brevoort), Pacific salmon *Oncorhynchus* spp., and various squids (Ueno et al. 1990). In water column of the eastern Bering Sea, species most frequently caught with smooth lumpsucker were walleye pollock, Pacific herring, Pacific salmon, capelin *Mallotus villosus* (Müller), eulachon *Thaleichthys pacificus* (Richardson), and various squids (Yoshida and Yamaguchi 1985, Brodeur et al. 1999). During the eastern Bering Sea summer salmon survey (Morita et al. 2007) most frequently caught together with smooth lumpsucker were Pacific salmon, walleye pollock, and Atka mackerel *Pleurogrammus monopterygius* (Pallas).

In the Gulf of Alaska, mid-water trawl catches (apart from smooth lumpsucker) most frequently contained walleye pollock, eulachon, capelin, Pacific herring, arrowtooth flounder *Atheresthes stomias* (Jordan & Gilbert), flathead sole *Hippoglossoides elassodon* Jordan & Gilbert, Pacific hake *Merluccius productus* (Ayres), northern smoothtongue *Leuroglossus schmidti* Rass, Pacific viperfish *Chauliodus macouni* Bean, and various squids (Csepp et al. 2011, Romain et al. 2012).

Data on species composition of bottom trawl catches containing smooth lumpsucker are very limited. During recent eastern Bering Sea bottom trawl survey (Hoff 2016), frequency of occurrence of smooth lumpsucker in catches was 30.2% with most frequently occurred Aleutian skate *Bathyraja aleutica* (Gilbert) – 77.8%, Kamchatka flounder *Atheresthes evermanni* Jordan & Starks – 77.8%, Greenland halibut – 67.2%, giant grenadier *Albatrossia pectoralis* (Gilbert) – 64.0%, shortspine thornyhead *Sebastolobus alascanus* Bean – 63.5%, arrowtooth flounder – 52.9%, Commander squid – 52.4% and other species less than 50%.

Composition of bottom trawl catches in the Gulf of Alaska containing species considered were notably different with most frequently caught slender sole *Lyopsetta exilis* (Jordan & Gilbert), sculpins of the genus *Triglops*, sturgeon poacher *Podothecus accipenserinus* (Tilesius), spinyhead sculpin *Dasycottus setiger* Bean, shortfin eelpout *Lycodes brevipes* Bean, and capelin (Mueter and Norcross 2002). Co-occurring species in catches with smooth lumpsucker in the northern Sea of Japan differ considerably from those in Pacific waters off the northern Kuril Islands, Eastern Bering Sea and the Gulf of Alaska due to differences in species composition of communities of above-mentioned areas that are located in different zoogeographic provinces.

As for mid-water trawls, some species are common for the northwestern Sea of Japan and other areas, for instance walleye pollock, Pacific herring, Pacific salmon, and squids in the Bering Sea and Gulf of Alaska (Yoshida and Yamaguchi 1985, Brodeur et al. 1999, Morita et al. 2007, Csepp et al. 2011, Romain et al. 2012) and Pacific salmon, Japanese sardine, Japanese anchovy, and squids off Hokkaido and Kuril Islands (Ueno et al. 1990).

The analysis of published and our own data shows that smooth lumpsucker occupies specific ecological niche consuming predominantly coelenterates (Yoshida and Yamaguchi 1985, Arai 1988, Ates 1988) and therefore does not represent potential predator or food competitor for the majority of fish inhabiting the same biotopes. The species cannot be considered as common prey for predatory fish and squid due to its specific lifestyle and very rare occurrence in predator stomach records (Yang and Livingston 1988, Orlov 1997).

Biomass and demography

It should be noted that in our study area frequency of occurrence (FO) of smooth lumpsucker is considerably lower as compared to the Bering Sea. Thus, in our catches its FO was 5.1% in midwater trawls and 4.9% in bottom trawls while in the midwater trawl catches in the western Bering Sea its FO made up 8.5-39.0% (Brodeur et al.1999, Chodakov et al. 2004), 50.0% – in the southeastern Bering Sea (Sinclair and Stabeno 2002), and 76.9% – in the central Bering Sea (Donut Hole) (Glubokov and Popov 2004).

The data on the absolute values of smooth lumpsucker estimated biomass in various parts of species' range in rather limited. Il'inskii and Radchenko (1992) estimated biomass of this species in the western Bering Sea as 14,250-73,190 metric tons that is at least 4.5-23 times more than in the area of our research. In the eastern Bering Sea it was recently estimated as 378 t (Hoff 2016) that is 6-8 times less as compared to recent estimations of biomass of this species within Russian EEZ in the Sea of Japan. There are the data on relative biomass (kg per km^2) of the species under consideration within the Russian EEZ in the Sea of Japan, Sea of Okhotsk, western Bering Sea, and Pacific Ocean off Kamchatka and Kuril Islands (Shuntov and Bocharov 2003, 2004a, 2004b, 2005, 2006, 2012a, 2012b, 2012c, 2014a, 2014b, 2014c). However, these data are hardly comparable with our estimations of absolute values of smooth lumpsucker biomass.

It is known that abundance of smooth lumpsucker might undergo dramatic changes, from unanticipated arrivals of large number of fish to coastal waters to their complete disappearance (Doak et al. 2008, Hoff 2016, Conner et al. 2017). The possible reasons for such extreme changes in smooth lumpsucker abundance are still poorly understood. The considerable recent increase of smooth lumpsucker biomass in the Sea of Japan, in our opinion, is associated with the rise of abundance of the species within its entire range. Thus, in adjacent Sea of Okhotsk mean density of smooth lumpsucker in research surveys during 1984-2009 increased from 1.2 to 11.6 t per km^2 (i.e. 10 times); in some areas (TINRO Basin) its density recently reached 53.5 t per km^2 (Shuntov and Bocharov 2014c). According to data (available at http://www.afsc.noaa.gov/RACE/groundfish/survy_data/data.htm) came from research surveys of AFSC (Alaska Fisheries Science Center), catch per unit effort (CPUE, kg per ha) increased from 0.22-0.29 in 1983-1986 to 0.46-0.79 in 2004-2006 off the Aleutian Islands and from 0.41 in 1984-1987 to 0.81 in 2007 in the Gulf of Alaska. Data of AFSC observers (available at http://www.afsc.noaa.gov/FMA/fma_database.htm) also testify to increase of smooth lumpsucker abundance in Alaskan waters. Thus, in 1994-1995 mean catch of species under consideration made up 17.4-25.9 kg (0.0017 to 0.0025% of total catch) while in 2001-2003 respective values increased to 39.2-89.9 kg and 0.0082-0.0282%. Notable increase in occurrence and catch rates of smooth lumpsucker in early 2000s, as compared to 1990s, were noted in Pacific waters of the northern Kuril Islands and southeastern Kamchatka (Orlov and Tokranov 2008). The rise of the total catch of this species in 2000-2006 was registered also in waters of Hokkaido (Yoshida and Mihara 2015).

The factors determining recent changes of smooth lumpsucker abundance in the North Pacific in the whole and in the Sea of Japan in particular are largerly unknown. However, it is possible to suggest that they may relate to the changes in abundance of recruitment that are associated with rather short life span of the species under consideration. There are no studies of age and growth of smooth lumpsucker. However, maximum age of its relative, lumpfish *Cyclopterus lumpus* L., does not exceed 10 years (Davenport 1985). Since spawning of smooth lumpsucker, similarly to that of lumpfish, occurs in shallow coastal waters, survival of its eggs and larvae largerly depends on many factors, such as storms, temperature conditions, currents, predation by invertebrates, fishes and marine birds (Davenport 1985).

Conclusion

Smooth lumpsucker in the Russian EEZ has wide distribution both horizontally and vertically. It is less abundant in small bays and in the northern Tatar Strait (north to 50°N). Despite wide bathymetric (0 to 940 m) and temperature (-1.1 to +12.2°C) ranges, this species prefers depths 400-800 m and temperatures 0-1°C. Size compositions of fish caught in water column and near the bottom differ considerably. In the water column its mean length was 17.9 cm while near the bottom it was 28.1 cm that is related to species life history. The estimated biomass of smooth lumpsucker observed in the northern Primorye in 2003 was about 3000 t that is about 2% of the total fish biomass in the area.

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