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DISTRIBUTION AND SOME BIOLOGICAL FEATURES OF FOUR POORLY STUDIED DEEP BENTHIC FLATFISHES (PLEURONECTIFORMES: PLEURONECTIDAE) IN THE NORTHWESTERN PACIFIC OCEAN

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ABSTRACT. – Deepsea sole, *Embassichthys bathybius* (Gilbert, 1891), Korean flounder, *Glyptocephalus stelleri* (Schmidt, 1904), rex sole, *G. zachirus* (Lockington, 1879) and slime flounder, *Microstomus achne* (Jordan & Starks, 1904) are rare flatfishes found off the Northern Kuril Islands and Southeastern Kamchatka. Data on their distribution and biology are rather scarce. Some quantitative indices of occurrence of these flatfishes in the study area, patterns of their spatial and vertical distributions, catch frequencies and occurrences based on bottom temperature, time of day and season and other multi-year aspects are provided. Data on the species co-occurring in catches with these flatfishes are also given. Size distributions and relationships between body length and weight are presented as well. Spatial distributions of the four species demonstrate their preference for three areas: the Southeastern Kamchatka Peninsula coast, the Paramushir Island coast and an underwater plateau in the Southern part of the study area. These three locations coincide with anti-cyclonic quasi-stationary eddies. Analysis of multi-year data showed that the abundances of the flatfishes in the study area fluctuate considerably with the rex sole and slime flounder being most common in the study area during autumn months, while the deepsea sole and Korean flounder occurred mostly during the spring - summer season. All species were caught predominantly during daylight hours.

KEY WORDS. – Distribution, biology, deepsea sole, Korean flounder, rex sole, slime flounder, Northern Kuril Islands, Southeastern Kamchatka.

INTRODUCTION

The ichthyofauna of the righteye flounders (Pleuronectidae) in the Pacific waters off the Northern Kurils and Southeastern Kamchatka is quite diverse and comprises of about 20 species (Fedorov, 2000; Sheiko & Fedorov, 2000). Most flounders examined from the area were found in relatively shallow water and a larger portion of their life cycle takes place on the continental shelf. These fishes will only go into deeper water during winter and become distributed in the upper parts of the continental slope. Four species of halibut that spend most of their lives on the continental slope are exceptions to this: the Pacific halibut (*Hippoglossus stenolepis*), Greenland halibut (*Reinhardtius hippoglossoides matsuurae*), Kamchatka flounder (*Atheresthes evermanni*) and arrowtooth flounder (*A. stomias*). To some extent, the deepwater habitat is characteristic of the roughscale sole (*Clidoderma asperrimum*), deepsea sole (*Embassichthys bathybius*), Korean flounder (*Glyptocephalus stelleri*), rex sole (*G. zachirus*) and the slime flounder (*Microstomus achne*). The Pacific and Greenland halibuts and Kamchatka flounder are the abundant species in the research area and their patterns of distribution and biological features have been well-studied (Sheiko & Fedorov, 2000). Despite the rare occurrence of the arrowtooth flounder and the roughscale sole off the Kurils and Kamchatka (Sheiko & Fedorov, 2000), their distribution patterns and biology have been well-reviewed in recent years (Orlov & Moukhametov, 2001a, 2001b; Tokranov & Orlov, 2003). As for the four rare species of flounders in our study, studies have been done on taxonomy (Hubbs, 1932; Norman, 1934; Rass, 1950; Sakamoto, 1984; Kim & Youn, 1994; Cooper & Chapleau, 1998; Evseenko, 2004) and general information regarding their zoogeography, depth ranges and maximum sizes (Clemens & Wilby, 1961; Hart, 1973; Eschmeyer et al., 1983; Fadeev, 1987; Masuda & Allen, 1987; Lindberg & Fedorov, 1993; Vetter et al., 1994; Amaoka et al., 1995; Kramer et al., 1995; Borets, 2000; Fedorov, 2000; Sheiko & Fedorov, 2000; Orlov, 2001; Novikov et al., 2002; Fedorov et al., 2003).

The main purpose of this paper is to: 1) provide some quantitative indices of the occurrence of the four flatfish species in the Pacific waters off the Northern Kuril Islands and Southeastern Kamchatka; 2) elucidate their spatial patterns; 3) analyze their catch frequencies and occurrences based on bottom temperature, time of day, season and other multi-year aspects; 4) present the data on species co-occurring in catches with these flatfish species and 5) determine their size distributions and the relationship between body length and weight.

MATERIALS AND METHODS

This paper is based on the materials sampled in the framework of the scientific program conducted for inadequately-studied or insufficiently-utilized species found on the continental slope of the Far Eastern seas. This paper presents results of analysis of catches from over 10,000 bottom hauls made between March - December yearly from 1992 to 2002 off the Northern Kuril Islands and Southeastern Kamchatka (between 47º50'N and 52º00'N at depths of 100 - 850 m).

The Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), as well as those of Kamchatka (KamchatNIRO) and Sakhalin (SakhNIRO) conducted over 50 joint research cruises where the distribution and biological data on four rare flatfish species were collected. Collection was made by Japanese trawlers (TOMI-MARU 53, TOMI-MARU 82 and TORA-MARU 58) which were specially equipped for ground hauls on parts of the continental slope having rough substrates. The bottom trawls have both a vertical (5 - 7 m) and a horizontal (25 m) opening and trawlings were conducted at all hours. The mean speed was 3.6 knots. The temperature at the depth of the haul (bottom temperatures) was measured during most of the hauls. As the duration of hauls during the cruises varied between half an hour and 10 hours, all catches were subsequently adjusted to standard 1 hour hauls.

The distribution of individual species by depth and bottom temperatures was analyzed according to the percentage of their occurrence calculated from the hauls averaged to one hour hauls. The sample sizes (n) for the analysis of species occurrence, spatial distributions, bottom temperature preferences, co-occurring species composition, diurnal, seasonal and multi-year changes of catch rates and frequency of occurrence were as follows: deepsea sole (n = 105), Korean flounder (n = 34), rex sole (n = 22) and slime flounder (n = 36). The sample sizes (n) for determining frequency distributions of lengths (measured by total length, TL, in cm) were as follows: deepsea sole (n = 138), Korean flounder (n = 38), rex sole (n = 29) and slime flounder (n = 38). The samples sizes (n) for length-weight relationship determinations were as follows: deepsea sole (n = 113), Korean flounder (n = 28), rex sole (n = 24) and slime flounder (n = 26). The relationship between length of fish (L, cm) and weight (W, g) is described by $W = a L^b$, where *a* and *b* are linear and exponential coefficients, respectively.

RESULTS AND DISCUSSION

General information and occurrence in the study area. – The range of distribution of the deepsea sole is between Sagami Bay on the Honshu side of the Pacific (the Asian coast) in the Southeast, the US/Mexico border (the American coast) in the Southwest, Navarin Cape in the Bering Sea in the North (Fedorov, 1967; Amaoka et al., 1981; Eschmeyer et al., 1983). This species can also be found on the seamounts of the Hawaiian and Emperor Ridges (Fadeev, 1987). It is most abundant in waters off the West coast of the US (Orlov, 2000). Its overall occurrence is very rare and it is of no economic importance (Kramer et al., 1995). Data on the life history of the species have been limited to descriptions of the eggs and larvae (Richardson, 1981) and some biological data from the Western Bering Sea (Orlov, 2000). In the area surveyed, the deepsea sole occurred more often than the other species (105 captures). However, catches of this species were the least compared to the other three species (Table 1) and not exceeding six individuals per one hour haul (0.5 individual per hour on the average).

The Korean flounder occurs exclusively on the Asian side of the North Pacific between the Pribiloff Islands in the Bering Sea in the North and Inubo Cape in Honshu in the South, which includes the Sea of Japan and Okhotsk Sea (Lindberg & Fedorov, 1993). It is most abundant at the Peter the Great Bay, Primorie, off the Southwest Sakhalin and Southern Kurils (Fadeev, 1987). This species is of commercial importance and is harvested by bottom trawls (Kramer et al., 1995; Novikov et al., 2002; Fedorov et al., 2003). Data for this species is available for the Pacific waters off Japan and the Russian waters in the Sea of Japan, off the Southern Kurils and Southern Sakhalin (Hashimoto, 1953; Mikawa, 1953; Druzhinin, 1954; Mikulich, 1954; Hayase & Hamai, 1974; Uchino, 1982; Pushchina, 2000; Shvydky & Vdovin, 2001). There was no data available on the Korean flounder in the study area where it is regarded to be a rare species (Sheiko & Fedorov, 2000). Its occurrence during the research period was about one-third of that of the deepsea sole (34 captures) and the catches did not exceed eight individuals per one hour haul (0.8 individual per hour on the average).

The rex sole is a typical representative of the American ichthyofauna which is distributed predominantly along the American coast between Southern California and the Southeastern Bering Sea (Allen & Smith, 1988). There have been scarce captures of it in the Asian waters of the Western Bering Sea (Kulikov, 1964a; Orlov, 2000), near the Commander Islands (Kulikov, 1964b) and Southeastern Kamchatka (Tokranov & Vinnikov, 2000). It is an important bottom trawl fishing target in American waters because of its significant abundance and commercial value (Hoise & Horton, 1977; Kramer et al., 1995). It is a prey item for pinnipeds (Lowry et al., 1990; Browne et al., 2001). All the information regarding the distribution and biology of the rex sole has been concentrated in the Eastern Pacific (Mineva, 1964; Pearcy et al., 1977; Pearcy, 1978; Pearcy & Hancock, 1978). This species occurred most rarely in the study area

Table 1. Some quantitative indices of occurrence of deepsea sole, Korean flounder, rex sole and slime flounder in catches within the Pacific waters off the Northern Kuril Islands and Southeastern Kamchatka from 1993 to 2002. The minimum and maximum values are given (underlined), followed by the mean values.

Species	Proportion in Catches (%)	Number of Fish Caught		Weight of Fish Caught (kg)		Depth (m)	Bottom Temperature (°C)	Length (cm)	Weight (g)	Number of Hauls with Species
		Total	Per Hour Trawling	Total	Per Hour Trawling					
Deepsea sole (*Embassichthys bathybius*)	<u>0.001 - 0.770</u> 0.091	<u>1 - 30</u> 2.638	<u>0 - 6</u> 0.457	<u>0 - 15</u> 2.143	<u>0 - 8</u> 0.438	<u>122 - 793</u> 526.2	<u>1.2 - 4.2</u> 2.71	<u>18 - 65</u> 39.51	<u>100 - 3,900</u> 948.3	105
Korean flounder (*Glyptocephalus stelleri*)	<u>0.001 - 0.966</u> 0.094	<u>1 - 8</u> 1.823	<u>0 - 8</u> 0.765	<u>0 - 8</u> 1.529	<u>0 - 6</u> 0.765	<u>132 - 630</u> 332.6	<u>0.4 - 3.45</u> 1.93	<u>22 - 62</u> 40.99	<u>60 - 2,700</u> 784.9	34
Rex sole (*Glyptocephalus zachirus*)	<u>0 - 0.123</u> 0.015	<u>1 - 5</u> 1.364	<u>0 - 10</u> 0.727	<u>0 - 1</u> 0.091	<u>0 - 1</u> 0.045	<u>102 - 513</u> 277.4	<u>3.2 - 3.6</u> 3.40	<u>20 - 40</u> 28.10	<u>50 - 1,000</u> 218.7	22
Slime flounder (*Microstomus achne*)	<u>0 - 1.792</u> 0.175	<u>1 - 205</u> 16.333	<u>0 - 74</u> 4.972	<u>0 - 48</u> 6.555	<u>0 - 17</u> 1.889	<u>109 - 583</u> 302.3	<u>0.05 - 3.5</u> 2.22	<u>21 - 53</u> 43.39	<u>40 - 1,480</u> 962.5	36

(22 captures). The maximum catches did not exceed 10 individuals per one hour haul, the average being 0.7 individual per hour of trawling.

The slime flounder occurs in the Northern part of the East China Sea, Yellow Sea, Sea of Japan, Southern Sea of Okhotsk near Southeastern Sakhalin, Hokkaido and along the Kuril Islands (Lindberg & Fedorov, 1993; Sheiko & Fedorov, 2000). Its maximum abundance was recorded in the Pacific waters off Japan where it is of some fisheries importance (Ishito, 1977). It has no commercial importance in Russian waters and is taken accidentally as by-catch with other flatfishes (Novikov et al., 2002). This species is believed to be rare within the study area (Sheiko & Fedorov, 2000). However, the slime flounder made up the greatest proportion of catches with up to 74 individuals (mean: ~ five individuals) or 17 kg (mean: 1.9 kg) per one hour haul.

Spatial distribution. **–** Within the area surveyed, the greatest density of the deepsea sole occurred on the West slope of the underwater elevation in the Southern part of the study area (Fig. 1A). It was caught sporadically between the Fourth Kuril Strait and the Southernmost tip of Kamchatka. The catches became larger (reaching three to five fish per hour haul) near the Southeast coast of the Peninsula. The pattern of distribution of the species comprises of three local centres: 1) an underwater plateau; 2) the coast of Paramushir Island and 3) Southeast Kamchatka which are in areas marked by quasi-stationary eddies. As the deepsea sole has pelagic eggs and larvae (Richardson, 1981), such a distribution pattern is probably related to the development of the early pelagic young of the species and its subsequent settlement within these eddies, which is typical of many species inhabiting the research area (Orlov, 2003). There are no data on the spatial distribution characteristics of this species in the other parts of the range.

The Korean flounder was most abundant opposite the Fourth Kuril Strait, where the per one hour haul exceeded five individuals (Fig. 1B). Individual catches of the species only occurred in the Southern part of the area studied. However, it was caught more frequently near the Southeast Kamchatka coast where over half of total captures were recorded. Also, maximum catches there were not greater than three to five fish per one hour haul, while a large proportion of catches contained single individuals. The spatial distribution pattern of the species probably indicates its penetration into the study area from the Sea of Okhotsk, mainly through the Fourth Kuril Strait. There is also the possibility of some individuals getting into the Pacific during summer through the relatively shallow First and Second Kuril Straits. The fact that many more individuals were found on a well-expressed (wide) shelf indicates that this species avoids regions having complex undulating substrates. It was not possible to analyze the relationship between the bottom relief and distribution based on the only reference on the spatial distribution of the Korean flounder in the Northwest Sea of Japan (Shvydky & Vdovin, 2001).

The spatial distribution of the rex sole was quite different from that of the other species. Its maximum catches, exceeding five fish per one hour haul, were exclusively recorded in the Northern part of the area examined, near the Southeastern coast of Kamchatka (Fig. 1C). There were only sporadic captures in the South of the First Kuril Strait. The major factor determining its distribution may be that the rex sole is a migrant from the waters off the Aleutian Islands adjacent to Southeast Kamchatka (Orlov, 2004). Its further penetration into the South is probably obstructed by the colder thermal conditions resulting from the advent of cold water from the Sea of Okhotsk and perhaps, a more complex bottom relief in the Southern part of the area. Judging from the data on distribution of this species in the East Pacific (East Bering Sea, the Aleutians, Gulf of Alaska, West coast of USA and Canada), the largest aggregations are observed where the shelf and slope are the broadest (Bakkala et al., 1992; Ronholt et al., 1994; Martin, 1997; Wilkins et al., 1998).

The pattern of spatial distribution of slime flounder (Fig. 1D) was very similar to that of the deepsea sole. The areas of larger concentrations were: 1) the Southern slope of the underwater plateau (catches over 50 individuals per hour) and 2) near Southeast Kamchatka (catches 11 - 50 individuals per hour). This species was caught sporadically in the central part of the region where there was only a single catch of 10 individuals in an hour's haul. As was the case with the deepsea sole, the presence of pelagic eggs and early juveniles in the species (Ishito, 1972; Ishito & Hashimoto, 1993), could probably explain the spatial distribution pattern described above where the species concentrates within the zone of quasi-stationary eddies. Recent information on the spatial distribution of the slime flounder pertains only to the waters off China and Japan (Ishito, 1972; Chen et al., 1992) and no occurrence data for Southeast Kamchatka have been available up till this present study.

Bathymetry. **–** The most benthic species is the deepsea sole, which was found in catches in the study area at depths between 122 and 793 m. The depth range for this species was 41 - 1,800 m (Sheiko & Fedorov, 2000), whereas the optimum range is between 500 - 950 m (Fedorov, 2000). Other data indicate that this flatfish prefers depths of > 645 m (Kramer et al., 1995) or 730 m (Hart, 1973). In the waters near the Kurils and Kamchatka, the deepsea sole most often occurred within 450 - 600 m (Fig. 2), though the maximum catches were recorded in two ranges: 300 - 350 m and 600 - 700 m. The existence of two depth ranges producing maximum catches may have to do with the seasonal differences in vertical distribution which has not been studied in this species. In Japanese waters, the captures of this species were recorded at depths of 335 - 850 m (Amaoka et al., 1981) and between 430 and 673 m in the West Bering Sea (Orlov, unpublished data).

The Korean flounder is known from depths of 8 - 1,600 m (Borets, 2000). It occurred in catches within depths of 132 - 630 m in the study area, though its highest frequency was between 200 and 300 m (Fig. 2). It became scarcer at greater depths, though catches became bigger. The catches reached

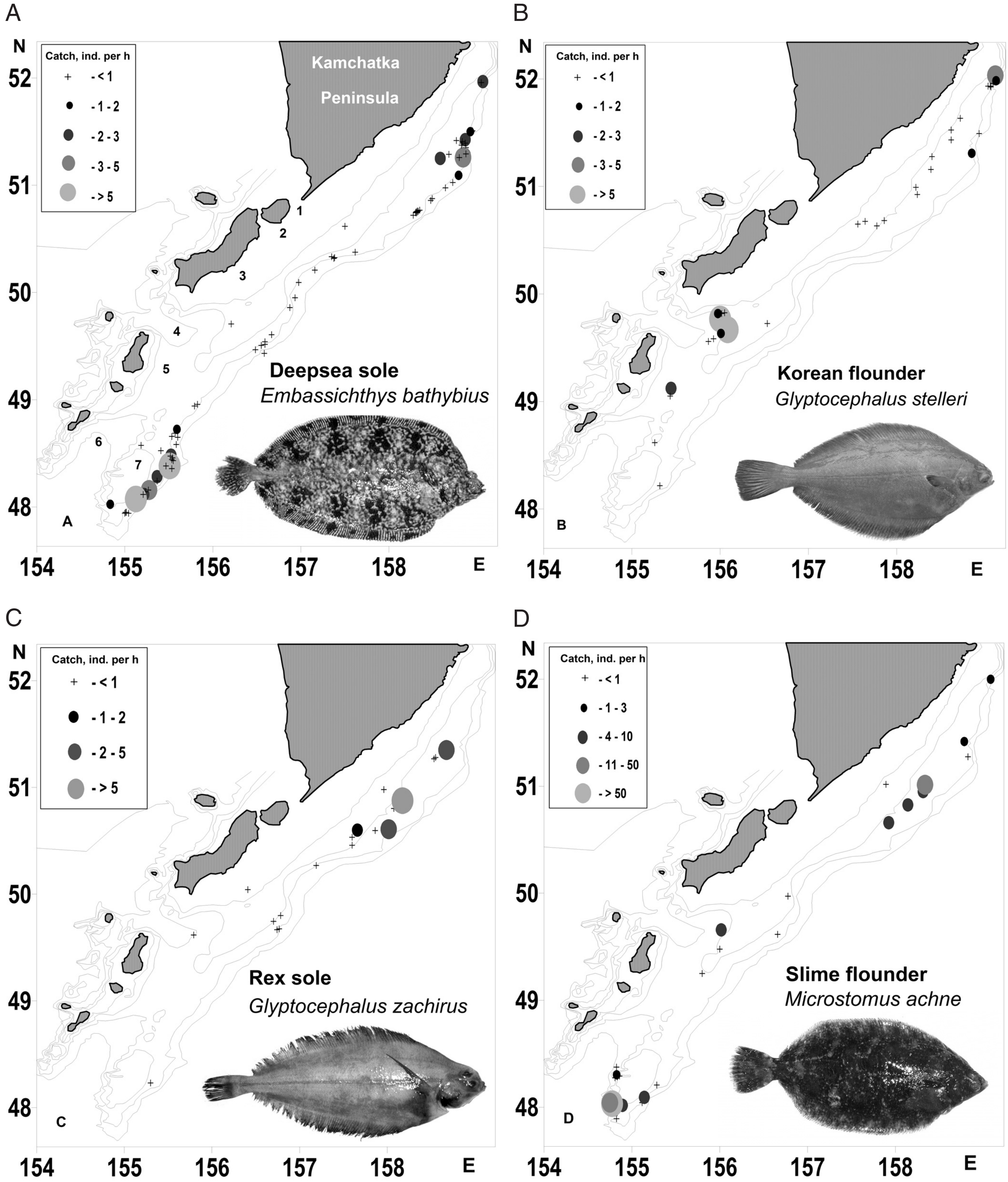

Fig. 1. Spatial distribution and relative abundance of the four poorly-studied deep benthic flatfishes. A) deepsea sole (*Embassichthys bathybius*), B) Korean flounder (*Glyptocephalus stelleri*), C) rex sole (*G. zachirus*), D) slime flounder (*Microstomus achne*). 1 = First Kuril Strait; 2 = Shumshu Island; 3 = Paramushir Island; 4 = Fourth Kuril Strait; 5 = Onekotan Island; 6 = Shiashkotan Island; 7 = underwater plateau; thin lines = 100, 200, 500 and 1,000 m isobaths; Catch, ind. per h = catches of individuals per one hour haul.

their maximum at depths of 300 - 350 m and 400 - 450 m. This type of vertical distribution is probably caused by the existence of well-pronounced seasonal migrations when it shifts for wintering to the continental slope up to 700 - 800 m depth and for spawning to the coastal waters at 15 - 200 m depth (Fadeev, 1987; Lindberg & Fedorov, 1993; Shvydky & Vdovin, 2001; Novikov et al., 2002).

The rex sole inhabits depths of 20 - 900 m within the study area (Fadeev, 2005) but is most abundant below the depth of 366 m (Hart, 1973). It would be difficult to determine the vertical distribution of this species in the study area based on our limited data. It can only be noted that this species occurred in catches most frequently at depths of 250 - 300 m (Fig. 2). In addition to this depth range, maximum catches were recorded at 350 - 400 m. The pattern of its vertical distribution is similar to that in other parts of the range where this species is most abundant at 300 - 500 m near the Aleutians and in the South Bering Sea (Ronholt et al., 1994), between 300 and 400 m in the West Bering Sea (Orlov, 2000) and between 100 and 200 m in the Gulf of Alaska (Martin, 1997). The average depths where the rex sole was recorded was 365 m off Washington and North Oregon and 437 m off South Oregon and North California (Lauth, 1997a, 1997b).

The depth range of the slime flounder is 20 - 610 m (Sheiko & Fedorov, 2000). Nothing is known of the optimum depth this species inhabits. It was recorded in catches at depths of 109 - 583 m in the study area. It was most frequently found over 300 m while the maximum catches were taken at depths of 250 - 300 m (Fig. 2). The vertical distribution pattern is similar to that of the Korean flounder, which probably also explains the presence of well-expressed seasonal migrations associated with the changes in the depth range of habitation during for wintering, spawning and feeding (Ishito, 1962, 1972, 1977).

Bottom temperature preference. – We were able to characterize the thermal habitation regime for three out of the four flatfishes as data for the rex sole was insufficient. However, it was possible to predict that this species favours higher water temperatures as it originates from the Northeastern Pacific where the water is generally much warmer than in the Northwestern half. It was seen in catches in a very narrow band with near-bottom temperatures of 3.2 - 3.6°C and mean of 3.4°C (Table 1). In the Northeast Pacific, this species was found in waters of bottom temperatures 2.5 - 11°C. Its maximum abundance was observed in the Gulf of Alaska where the temperatures near the bottom were between 3.0 and 4.5°C and in the Californian waters of 6.0 - 9.0°C (Fadeev, 1987). In the Southeast Bering Sea, this species hibernated in bottom temperatures of 3.7 - 3.9°C (Mineva, 1964).

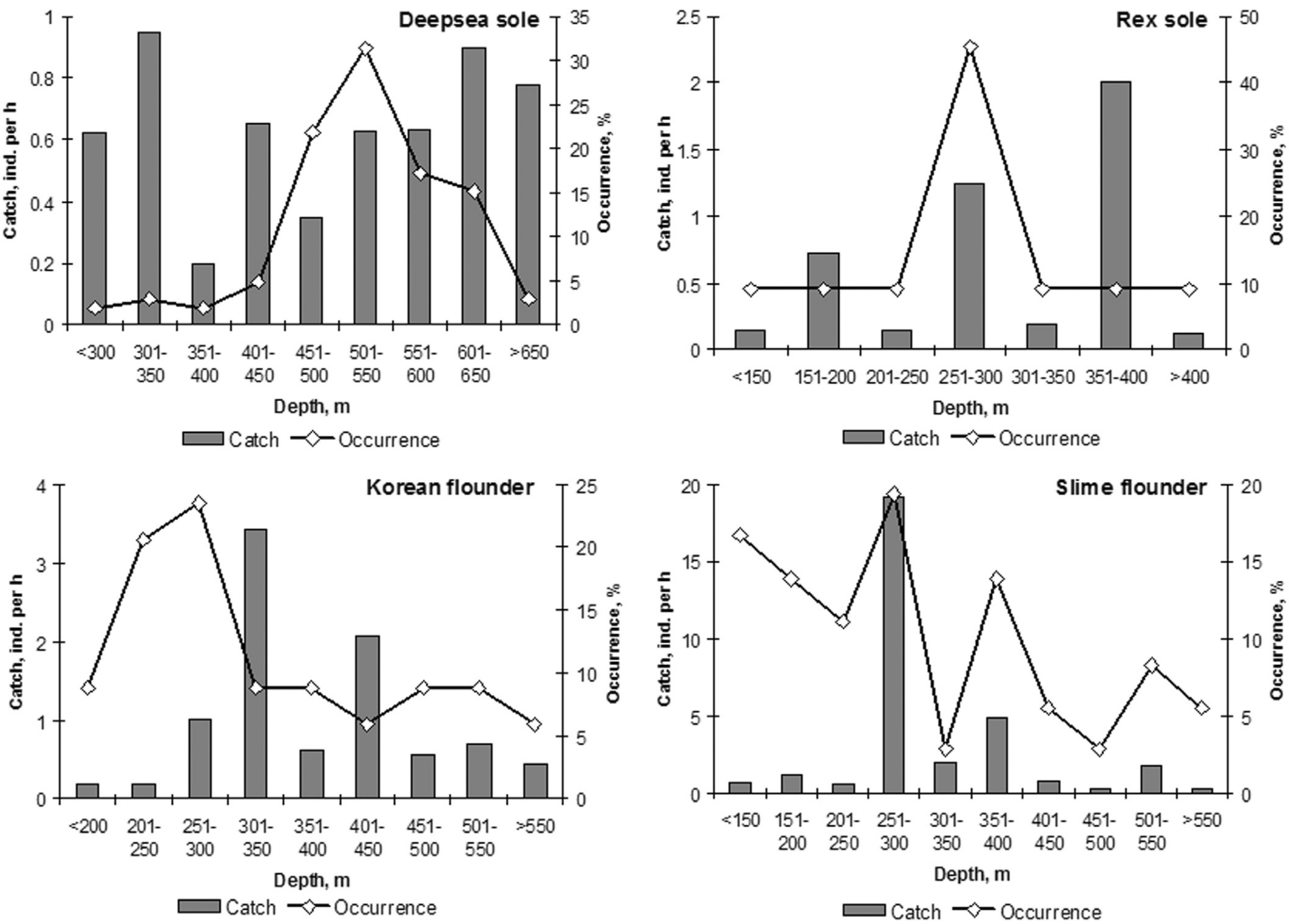

Fig. 2. Vertical distribution of the four poorly-studied deep benthic flatfish species in study area. Catch, ind. per h = catches of individuals per one hour haul.

Table 2. Species composition (frequency of occurrence, %) of catches containing rare flatfish species (Pleuronectidae) in the Pacific waters off the Northern Kuril Islands and Southeastern Kamchatka from 1992 to 2002. Only species with frequency of occurrence of > 50% are included.

Species	Frequency of Occurrence with Flatfishes Species Studied (%)			
	Deepsea sole	Slime Flounder	Korean Flounder	Rex Sole
Albatrossia pectoralis	87.6	+	+	+
Antimora microlepis	54.3	+	+	-
Atheresthes evermanni	86.7	+	82.3	63.6
Bathyagonus nigripinnis	61.9	+	+	+
Bathyraja aleutica	60.0	+	55.9	+
Bathyraja matsubarai	59.1	+	+	+
Bathyraja violacea	+	+	+	54.5
Berryteuthis magister	89.5	58.4	64.7	77.3
Bothrocara brunneum	59.1	+	+	+
Careproctus furcellus	71.4	+	64.7	63.6
Careproctus rastrinus	+	+	67.7	+
Coryphaenoides cinereus	85.8	+	+	-
Elassodiscus obscurus	58.1	+	+	-
Elassodiscus tremebundus	78.1	+	+	+
Gadus macrocephalus		+	79.4	77.3
Hippoglossoides elassodon	+	+	79.4	72.7
Hippoglossus stenolepis	+	+	73.5	72.7
Lepidopsetta polyxystra	+	+	82.4	81.8
Liparis ochotensis	+	+	+	50.0
Lycodes albolineatus	+	+	+	63.6
Lycodes brunneofasciatus	+	+	73.5	59.1
Malacocottus zonurus	73.3	77.8	73.5	68.2
Pleurogrammus monopterygius	+	58.3	+	63.6
Reinhardtius hippoglossoides	69.5	+	67.7	+
Sebastes alutus	+	58.3	55.9	+
Sebastes borealis	88.6	+	+	+
Sebastolobus alascanus	75.2	+	+	+
Sebastolobus macrochir	95.2	+	+	+
Theragra chalcogramma	+	58.3	88.2	86.4
Triglops scepticus	+	+	50.0	50.0
Number of hauls	105	36	34	22

+ = < 50% occurrence; - = species was not observed in catches.

There were no temperature data available for the other regions where the deepsea sole was distributed. In the study area, this species was recorded in regions with the bottom temperatures of 1.2 - 4.2°C (mean: 2.71°C). It was most frequently observed where the bottom temperatures were 2.0 - 2.5°C (Fig. 3), though the maximum catches were noted in bottom temperature ranges of 3.0 - 3.5°C.

The information regarding the temperature regime at the habitats of the Korean flounder was somewhat contradictory. Many authors tend to agree with the view that it lives in bottom temperatures of 1.0 - 14°C in the Sea of Japan (Fadeev, 1987; Lindberg & Fedorov, 1993; Novikov et al., 2002) and near West Kamchatka at 0 - 5°C (Fadeev, 1987) in the summer. Fadeev's (1987) data show that this species stayed at above-zero temperature zones during winter, while Shvydky & Vdovin (2001) pointed out that the winter temperature range was 0.1 - 0.7°C and Lindberg & Fedorov (1993) further indicated that the temperatures were between – 0.5 to 1.5°C. In the study area, the Korean flounder occurred at bottom temperatures of 0.4 - 3.5°C (mean: 1.93°C). It was within 1 - 2°C where both the frequency of occurrence and size of catches were at their maximum (Fig. 3).

No data was available on the habitat temperatures of the slime flounder. In the study area, this flatfish was found where the near-bottom temperatures were from 0.1 to 3.5°C (mean 2.22°C). The maximum occurrence and largest catches were recorded at temperatures above 3°C (Fig. 3).

Co-occurring species. **–** Nothing is known about the ecological environment of the four flatfish species. The catches containing all the four species taken on the Pacific side of the Kurils and Southeast Kamchatka also commonly netted darkfin sculpin (*Malacocottus zonurus)* and the red squid (*Berryteuthis magister)* with maximal occurrences of over 50% (Table 2). The catches containing the Korean flounder and rex sole were the most similar in terms of the species composition. The reason for this was the corresponding similarity in their spatial distributions. The species composition of catches containing the deepsea sole differed most greatly from those of the other species which could probably be due to the deepest depth habitat of this species and its greatest abundance in the area of the underwater plateau where the species composition is very specific. Species composition of co-occurring with slime flounder species was also very specific since the greater

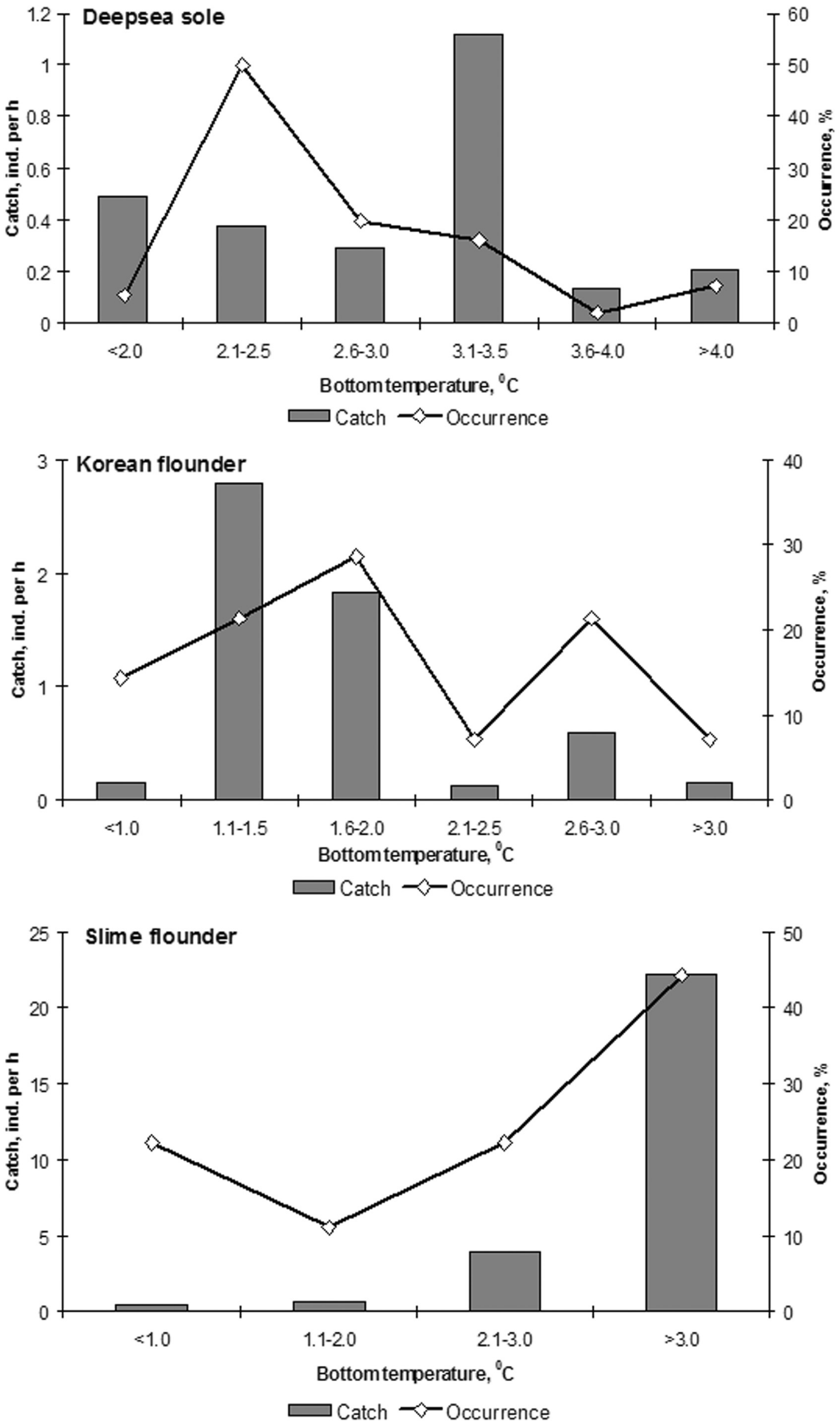

Fig. 3. Distribution of the deepsea sole (top), Korean flounder (center) and slime flounder (bottom) in study area depending on bottom temperature. No data for rex sole was available due to insufficient sample size. Catch, ind. per h = catches of individuals per one hour haul.

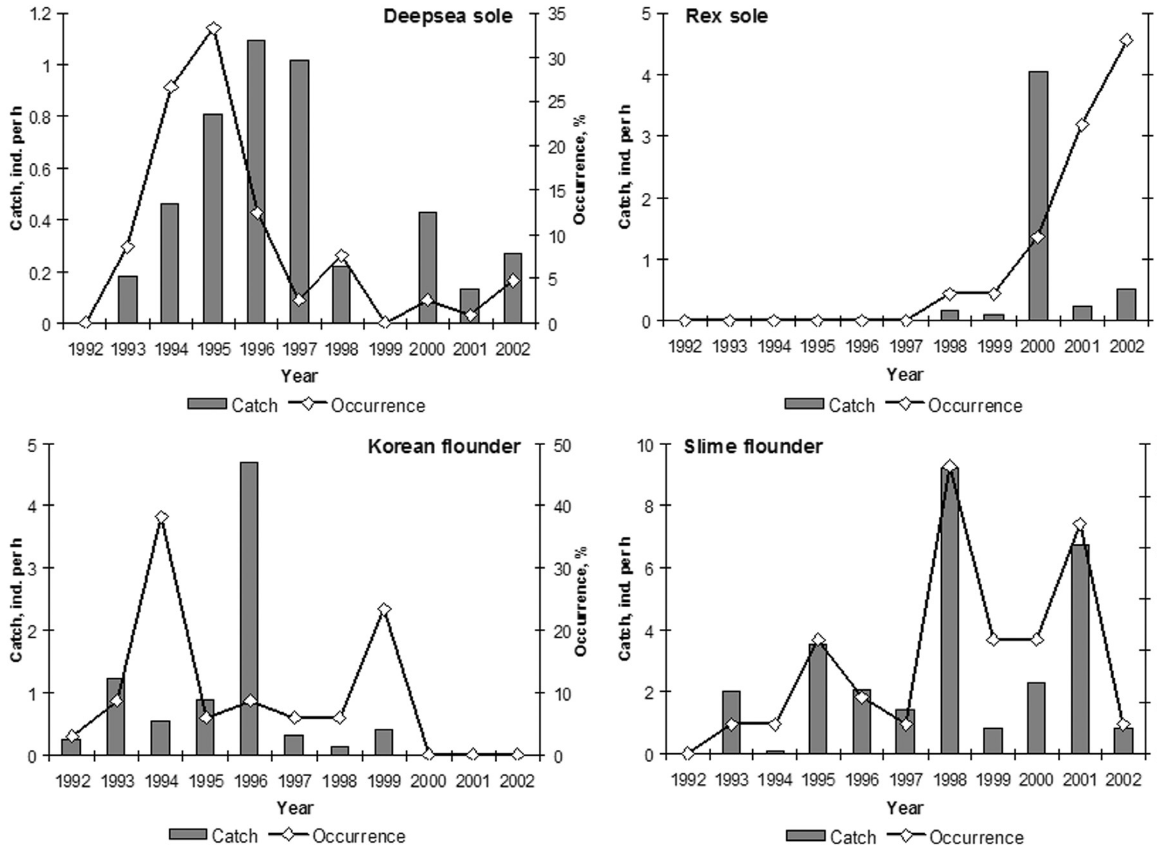

Fig. 4. Multi-annual changes of the four poorly-studied deep benthic flatfish species catch rates and occurrence in the study area from 1992 to 2002. Catch, ind. per h = catches of individuals per one hour haul.

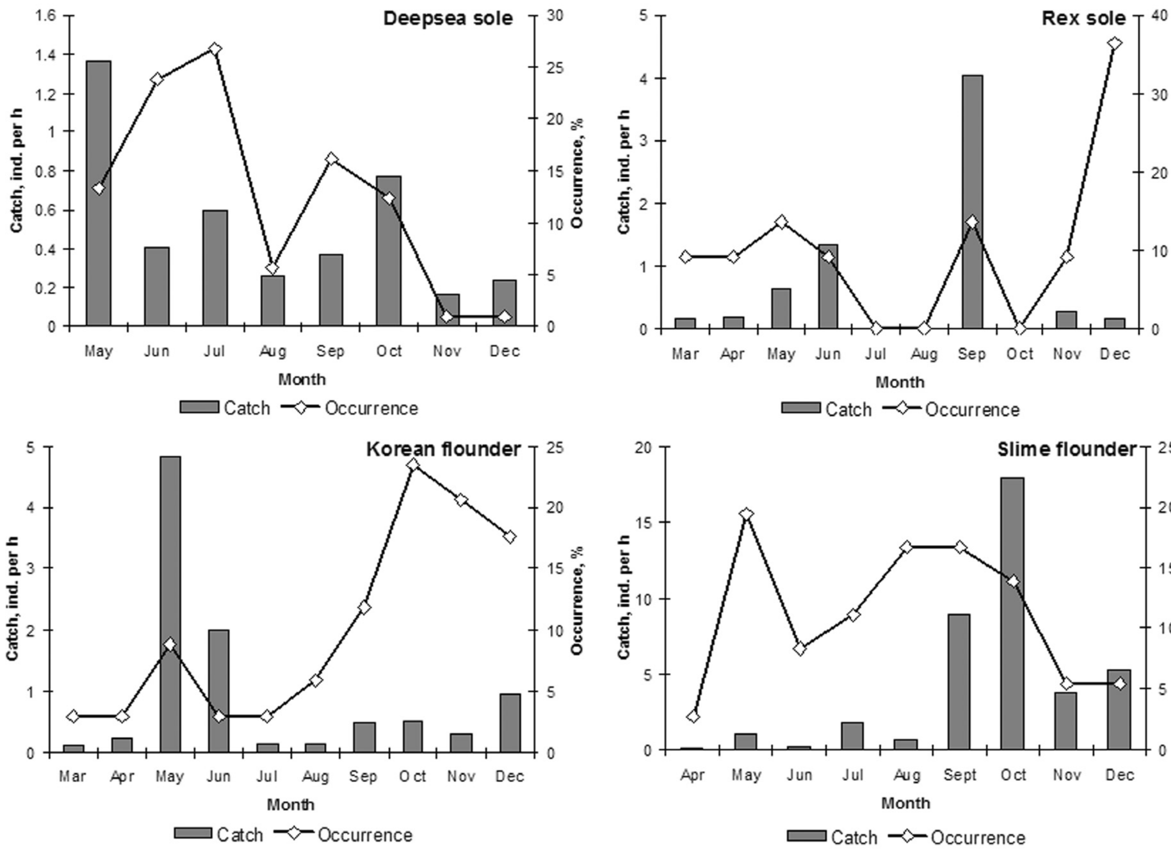

Fig. 5. Seasonal changes of the four poorly-studied deep benthic flatfish species catch rates and occurrence in study area. Catch, ind. per h = catches of individuals per one hour haul.

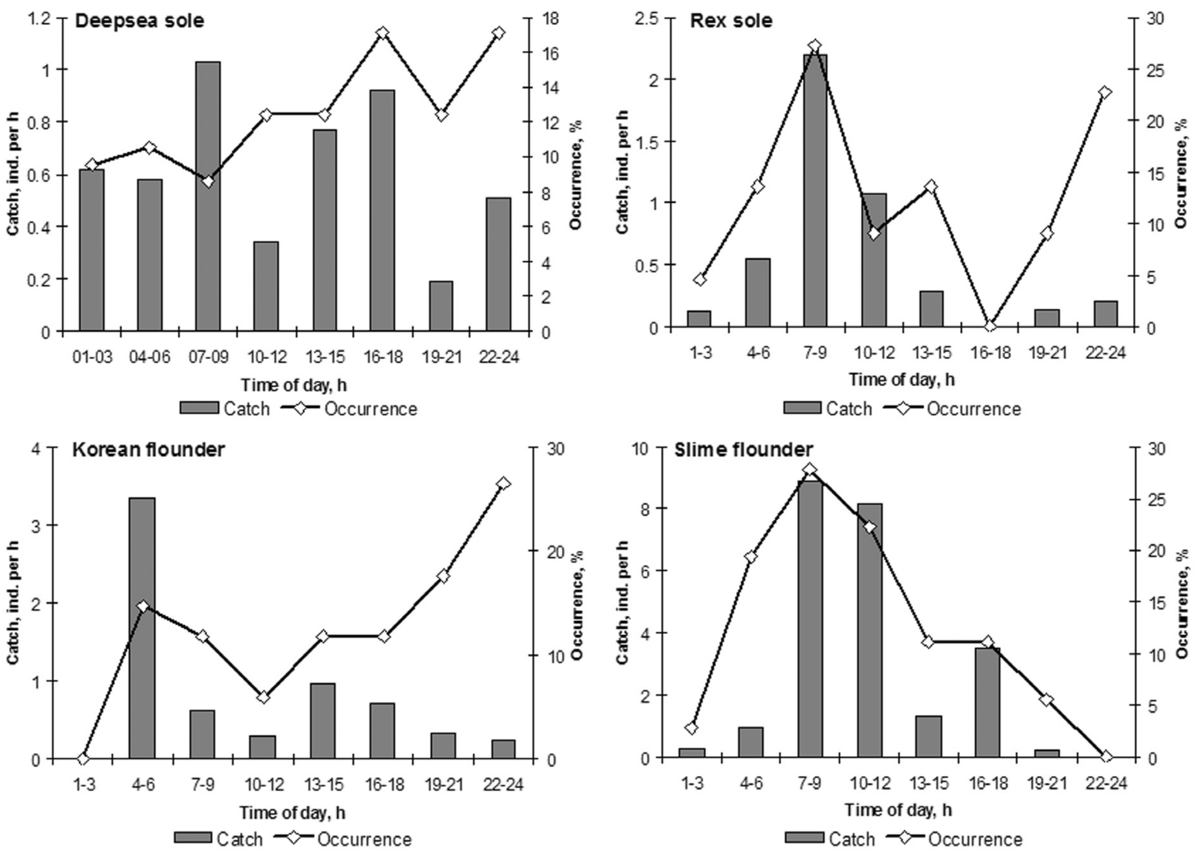

Fig. 6. Diurnal changes of the four poorly-studied deep benthic flatfish species catch rates and occurrence in study area. Catch, ind. per h = catches of individuals per one hour haul.

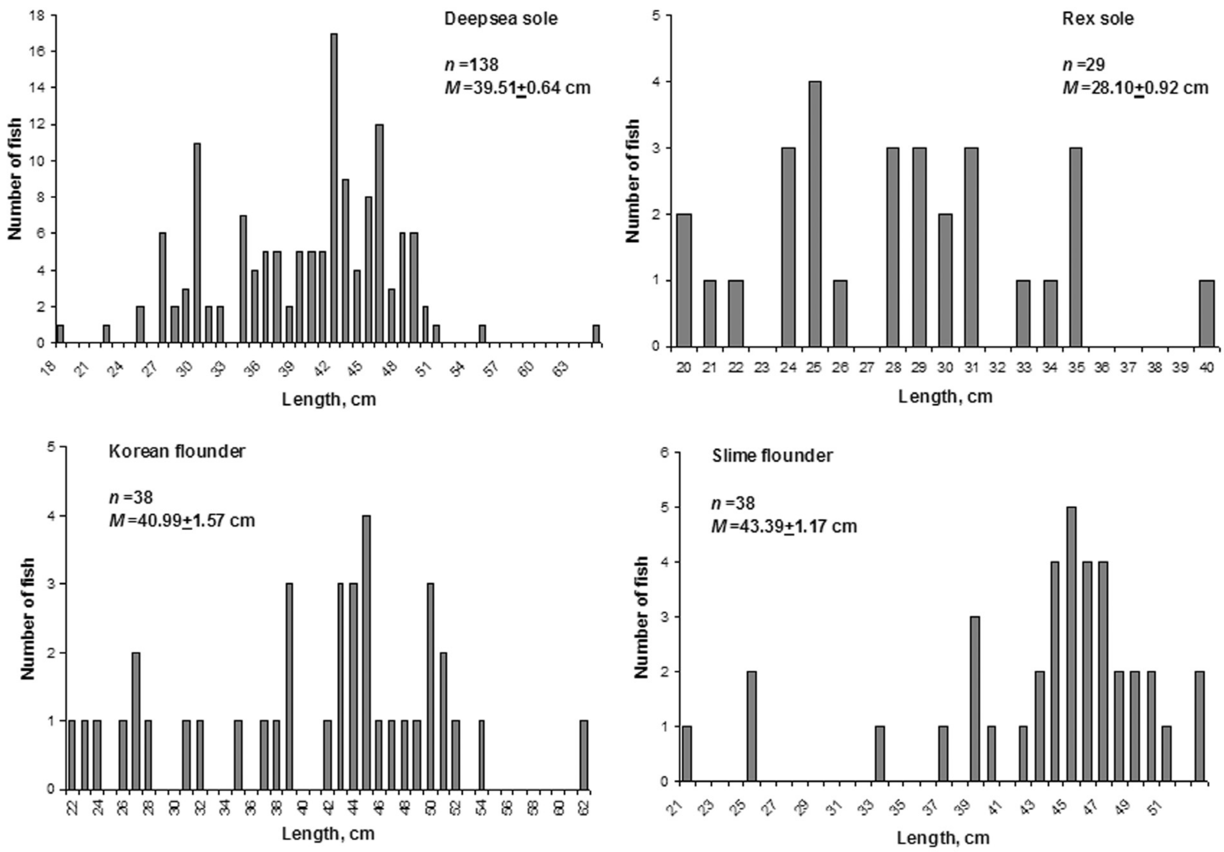

Fig. 7. Length-frequencies of the four poorly-studied deep benthic flatfish species in study area. n = number of fish measured; M = mean length ± standard error.

abundance of the slime flounder was noted at relatively shallower depths of the underwater plateau.

Multi-year changes of occurrence and catch rate. – We can draw the following conclusions from the multi-year occurrence dynamics and catch size of the four rare flatfish species in the study area (Fig. 4): 1) the occurrence and catches of the deepsea sole grew steadily from 1993 and started to decline in the mid-1990s, followed by stabilization at a low level; 2) a similar trend was observed in the case of the Korean flounder whose frequency and catches went down considerably since 1996; 3) an opposite picture was seen in the slime flounder and rex sole, with the former going up steadily until 1998 before a notable decline ensued and the latter increasing in frequency up to 2002 and beyond, since it was first recorded in the study area in 1998 (Tokranov & Vinnikov, 2000).

In our view, the above changes were mainly caused by the change in the climate system in the North Pacific in the late 1990s in the form of a significant warming of waters in the area surveyed. This resulted in the penetration of some species of American origin (the contiguous waters of the Aleutians) including the rex sole (Orlov, 2004). It is probably for that reason that the slime flounder and rex sole which favour warmer waters were more abundant in the research area in the second half of the 1990s and early 2000s. Conversely, the habitat conditions in the first half of the 1990s were more favourable for the deepsea sole and Korean flounder which prefer colder waters. The relative abundances of the slime flounder fluctuate from year to year in the Pacific waters off Japan and this may be associated with the size of migrating stocks (Ishito, 1977).

Seasonal changes of occurrence and catch frequencies. – The variations in the size of catches and frequency of occurrence in a year may reflect the seasonal changes in the distribution of the species examined (Fig. 5) as a function of various alternating phases in their life cycle (wintering, feeding and spawning). The deepsea sole was at peak abundance in spring and summer. Its catches and occurrence were somewhat lower in autumn and winter, which was probably caused by the fish moving to deeper layers as the near-bottom water become colder. The maximum catches of the Korean flounder were recorded in May and June. These were probably the months when a favorable thermal background is established, contributing to the expansion of this species from the Sea of Okhotsk. The greatest catches of the Korean flounder in May and June were probably related to its spawning occurring exclusively in the summer months (Lindberg & Fedorov, 1993; Shvydky &Vdovin, 2001; Novikov et al. 2002). The maximum occurrence of this flatfish in catches in the autumn and winter periods indicates that the Korean flounder was scattered throughout the surveyed area.

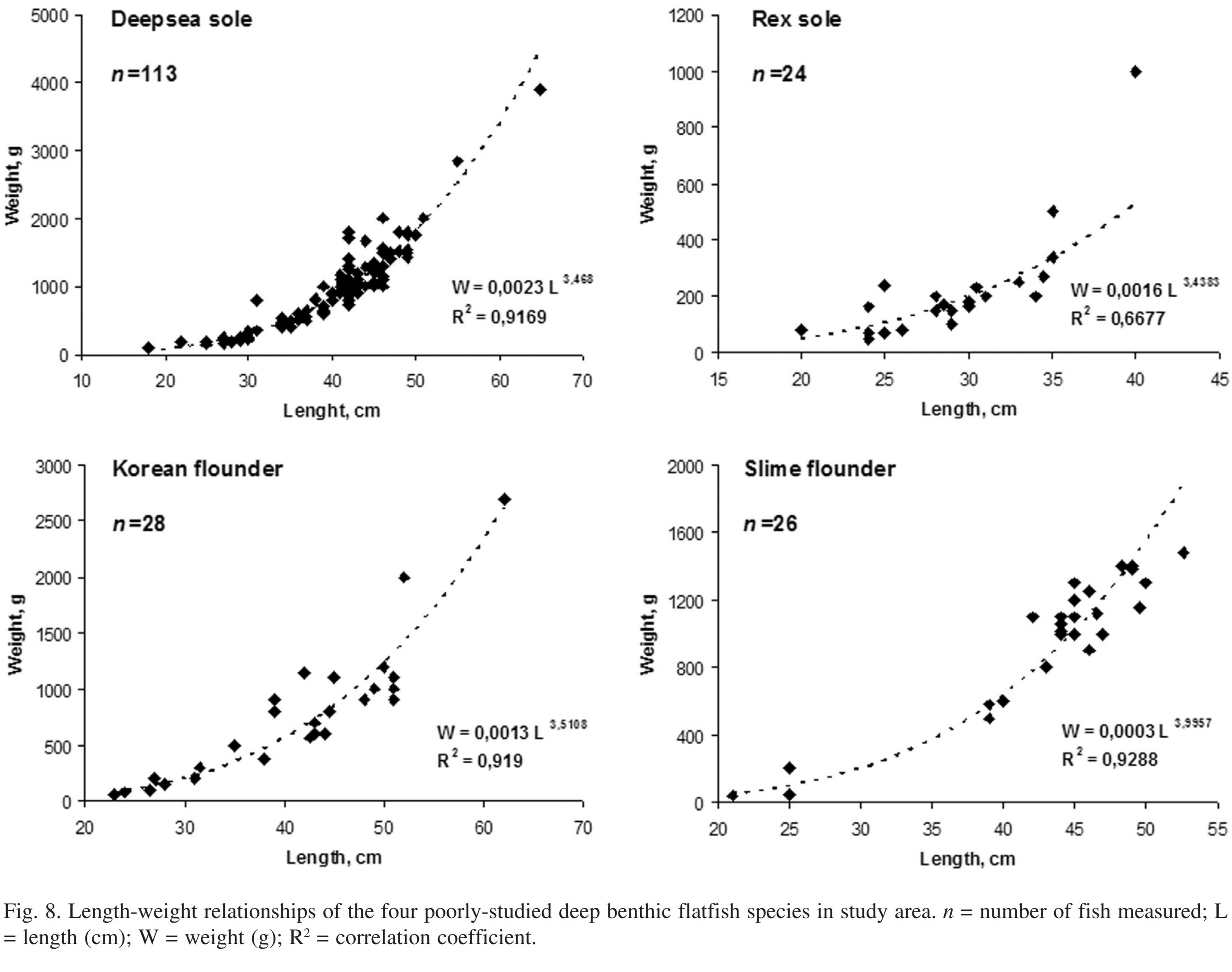

Fig. 8. Length-weight relationships of the four poorly-studied deep benthic flatfish species in study area. *n* = number of fish measured; L = length (cm); W = weight (g); R^2 = correlation coefficient.

The rex sole occurred most often in November and December though the catches reached their peak in September. The data available is inadequate to draw any conclusions regarding the pattern of its seasonal distribution. The maximum catches and occurrence of the slime flounder was observed in late summer and in autumn (i.e. during the period when the near-bottom layers in the study area get warmer), which supports the idea that the species prefers warmer water. In Japanese waters, this flatfish spawns in March - April, feeds from March - September and winters between October and February (Ishito, 1972). It is possible that its life stages in the area of study were attained somewhat later because of the colder thermal conditions. Therefore, it can be assumed that this species is sparsely distributed in the study area for the greater part of the year and will begin to form more dense concentrations by the end of feeding season and the beginning of wintering.

Diurnal changes of occurrence and catch frequencies. **–** The daily catch size variations and frequency dynamics of the species considered can be analyzed to give a probable evaluation of the diurnal distribution dynamics which may depend on the shift in the physiological cycle, behaviour and consequently lead to differences in the accessibility of the bottom trawls to the fish during various parts of the day (Fig. 6).

The catches and occurrences of the deepsea sole did not vary considerably with the time of day. Maximum indices of relative abundance of the deepsea sole occurred at 0700 - 0900 and 1300 - 1800 hours. The catches of the Korean flounder, rex sole and slime flounder reached their maximum during the daytime, gradually decreasing by midnight. The Korean flounder were caught with highest rates from 0400 - 0600 hours and the maximum values of indices of relative abundance of rex sole and slime flounder were recorded between 0700 and 1200 hours. The decline in catches and frequency during the night (1900 - 2400 hours) may indicate scattering of the fish at this time. No data were available on the differences in behavior of these species throughout the day. However, there is some information on the ability of the rex sole to dig itself into the substrate (Orlov, 2000). The data obtained may indicate that the behaviour of this species differs between daytime and night time. The activities of these species are likely to decrease significantly at night with the need to hide from predators and hence, they become less likely to be caught by bottom trawls. These flatfishes become more active during the daylight hours, seeking food and thus, being caught by the bottom trawls more often.

Length frequencies. **–** Data on the size composition of the four flatfishes were sorely lacking. Most publications only provided data on their extreme sizes. It had been believed that the deepsea sole's maximum length is 47 cm (Hart, 1973; Kramer et al., 1995; Borets, 2000). This species measured 40 - 50 cm in catches from the West Bering Sea (mean: 46.0 cm) and the mean weight was 1,329 g (Orlov, 2000). The deepsea sole in the study area measured 18 - 65 cm, the mean being 39.51 cm (Fig. 7), while the most abundant size classes were 30, 42 - 43 cm and 45 - 46 cm. The body weight of this flatfish varied between 100 - 3,900 g (mean: 948.3 g).

The data on the maximum size of the Korean flounder are contradictory. It was thought to be 40 cm (Amaoka et al., 1995), though most scientists believe it to be 50 cm (Lindberg & Fedorov, 1993; Borets, 2000; Novikov et al., 2002). The specimens caught in this study were 22 - 62 cm long (mean: 40.99 cm). Most fish were 41 - 45 cm long. The weight of the Korean flounder was between 60 - 2,700 g (mean: 784.9 g). In Aniva Bay (Southern Sakhalin), this flatfish was much smaller. The lengths of fish caught fluctuated between 17.5 and 42.6 cm (mean: 30.2 cm) and most were 26 - 34 cm. The body weight was 66 - 822 g (mean: 242 g) with the fish weighing 120 - 320 g predominated (Druzhinin, 1954).

The longest rex sole was believed to be 61 cm (Kramer et al., 1995). Its size composition varies significantly among various regions. The largest fish were recorded in the Southeast Bering Sea (20 - 60 cm; 150 - 1,500 g; the means were 48.1 cm and 949 g, respectively) and near the Aleutians (Mineva, 1964; Ronholt et al., 1994). The species is somewhat smaller in the Gulf of Alaska (mean: 35.7 cm) and in the East Bering Sea (32.5 cm) (Bakkala et al., 1992; Martin, 1997). The smallest were found near the West coast of the USA, where its mean length in catches was only 26.3 cm (Wilkins et al., 1998). In the West Bering Sea, the fish was 26 - 40 cm long (mean: 30.8 cm) with mean body weight of 313 g (Orlov, 2000). In the vicinity of the Commander Islands, the catches contained some individuals of 32 - 51 cm (Kulikov, 1964b). In the study area, the individuals caught were much smaller and lighter: 20 - 40 (mean: 28.1 cm) and 50 - 1,000 g (mean: 217.8 g). Individuals of 24 - 25 cm and 28 - 31 cm predominated.

According to Amaoka et al. (1995), the slime flounder may reach the length of 50 cm, whereas most authors suggest that it is 60 cm (Masuda & Allen, 1987; Lindberg & Fedorov, 1993; Borets, 2000; Sheiko & Fedorov, 2000; Novikov et al., 2002). Information on the size composition of this species is available only for the waters near China (Chen et al., 1992) where individuals of 12 - 48 cm were caught with the prevalent size being 18 - 30 cm. In the study area, the individuals caught were longer (21 - 53 cm; mean: 43.39 cm) and weighing 40 - 1,480 g (mean: 962.5 g).

Length-weight relationships. **–** Length-weight (L-W) relationship data for the four flatfishes are scarce. The relationship between these two parameters may characterize growth patterns (Zotina & Zotin, 1967). On the other hand, the power coefficient (*b*) of this equation may be different in the fish of the same species but belonging to different populations (Vinberg, 1971). There have been no length-weight relationship data in the deepsea sole. According to our data this relationship has a large degree of correlation ($R^2 = 0.917$), while the power coefficient, which in most of the fish species is close to three, is higher in this species (Fig. 8).

No length-weight relationship data was available for the Korean flounder. The body length and weight of this flatfish in the study area had a high proportionality with a high correlation of the parameters considered ($R^2 = 0.919$). As in the case of the deepsea sole, the equation's power coefficient was considerably over three.

The correlation of the length-weight relationship in the rex sole in the study area was of an average value ($R^2 = 0.668$), which is probably related to the scarcity of data. Nevertheless, the linear and power coefficients of the equation proved to be close to those for the Korean flounder which might be attributable to the generic closeness between these species and their similar growth patterns. In the other parts of the range of the former species, the values of the linear and the power coefficients of the equation for this species were 0.00284 and 3.531 for the Gulf of Alaska (Martin, 1997), 0.0018 and 3.387 for the Aleutian Islands (Ronholt et al., 1994) and 0.0238 and 2.692 for Washington and Oregon (Browne et al., 2001), respectively.

The length-weight relationship data for the slime flounder were limited to the waters off China (Chen et al., 1992) where the linear and power coefficients of the equation were 6.3×10^{-5} and 2.78 respectively. In the study area, the length and weight of this flatfish have a well-pronounced relationship with a high degree of correlation ($R^2 = 0.929$), while the coefficients were 0.0003 and 3.996, respectively.

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