ISSN 0032-9452, Journal of Ichthyology, 2017, Vol. 57, No. 2, pp. 228–256. © Pleiades Publishing, Ltd., 2017.
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Biological features of Common Fish Species in Olyutorsky-Navarin Region and the Adjacent Areas of the Bering Sea: 3. Righteye Flounders (Pleuronectidae)

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Received January 29, 2016

Abstract—Biological features of the seven abundant commercial species—the Pacific halibut *Hippoglossus stenolepis,* the Greenland halibut *Reinhardtius hippoglossoides*, the Alaska plaice *Pleuronectes quadritubercu-latus*, the northern rock sole *Lepidopsetta polyxystra*, the yellowfin sole *Limanda aspera*, the flathead sole *Hippoglossoides elassodon*, and the Bering flounder *H. robustus* (Pleuronectidae)—have been studied for a 20-year period (1995–2015). These species are present in the northwestern Bering Sea in the summer–autumn season; they form the gatherings in Olyutorsky-Navarin region. The size-weight spectra of the fish caught by different fishing gear has been analyzed, the peculiarities of the linear growth and the weight gain, as well as the spawning period and scale and the spawning conditions, have been described. The largest halibut specimens have been registered in the bottom setlines and gill nets, while flounders were in snurrevad catches; the smallest specimens have been observed in trawl catches. The abundant year-class in most of the studied species is seen well on the long-term plots of the fish size spectra and is tracked by the decrease of their biological parameters. The species that demand vast growing grounds (Pacific halibut, Alaska plaice, northern rock sole, and yellowfin sole) are characterized by a smaller average body size of the fish sampled in the coastal waters due to the prevalence of the young specimens in this area.

Keywords: Pleuronectidae, Pacific halibut *Hippoglossus stenolepis*, Greenland halibut *Reinhardtius hippoglossoides*, Alaska plaice *Pleuronectes quadrituberculatus*, northern rock sole *Lepidopsetta polyxystra*, yellowfin sole *Limanda aspera*, flat-headed flounders of genus *Hippoglossoides*, biology, Olyutorsky-Navarin region, Bering Sea

DOI: 10.1134/S0032945217020060

The study continues the series of publications aimed at describing the biology of the abundant and commercial fish species in Olyutorsky-Navarin region and the adjacent areas of the Bering Sea (Datsky, 2016, 2017). In the present publication, we analyze the abundant species of the righteye flounders (Pleuronectidae). Here, we provide the results of the comparative analysis of the size-weight spectra of the fish caught by different fishing gear, the peculiarities of the linear growth and the body weight increase, and we present the data on the spawning periods and scale, and the spawning conditions. The detailed description of materials and methods is given in the first publication of the series (Datsky, 2016).

RESULTS AND DISCUSSION

Pacific halibut *Hippoglossus stenolepis* is one of the largest studied species; it may reach the body length (*FL*, by Smith) 267 cm, the body weight 363 kg, and the age 55 years. Ultra-large fish are caught rarely, but the specimens *FL* 100–180 cm and body weight of up to 100 kg are found quite frequently, especially in the Bering Sea and Gulf of Alaska (*The Pacific Halibut*..., 1998; Munk, 2001; Mecklenburg et al., 2002; Fadeev, 2005). The report on the catch of the Pacific halibut *FL* 470 cm and body weight 423 kg (Fadeev, 1986, 1987; *The Pacific Halibut*..., 2014) was not documented officially.

In the northwestern Bering Sea, the Pacific halibut reaches *FL* 26–215 cm at the age 4–23 years. In the trawl catches, the specimens *FL* 45–80 cm and body weight 1.4–10.5 kg at the age 7–11 years dominate; in the setlines, those 53–120 cm at the age 7–13 years dominate (Datsky and Andronov, 2007). The ratio of the elder age groups of the Pacific halibut in this area is higher compared to the other regions of the Bering Sea (Novikov, 1974).

In Olyutorsky-Navarin region in the summer–autumn period, the Pacific halibut *FL* 12–100 cm (dominating *FL* 33–36, 50–51, 59–60 and 72 cm) was registered in the trawl catches (Figs. 1 and 2). The age of the growing fish varies from 4 up to 18 years; 7–

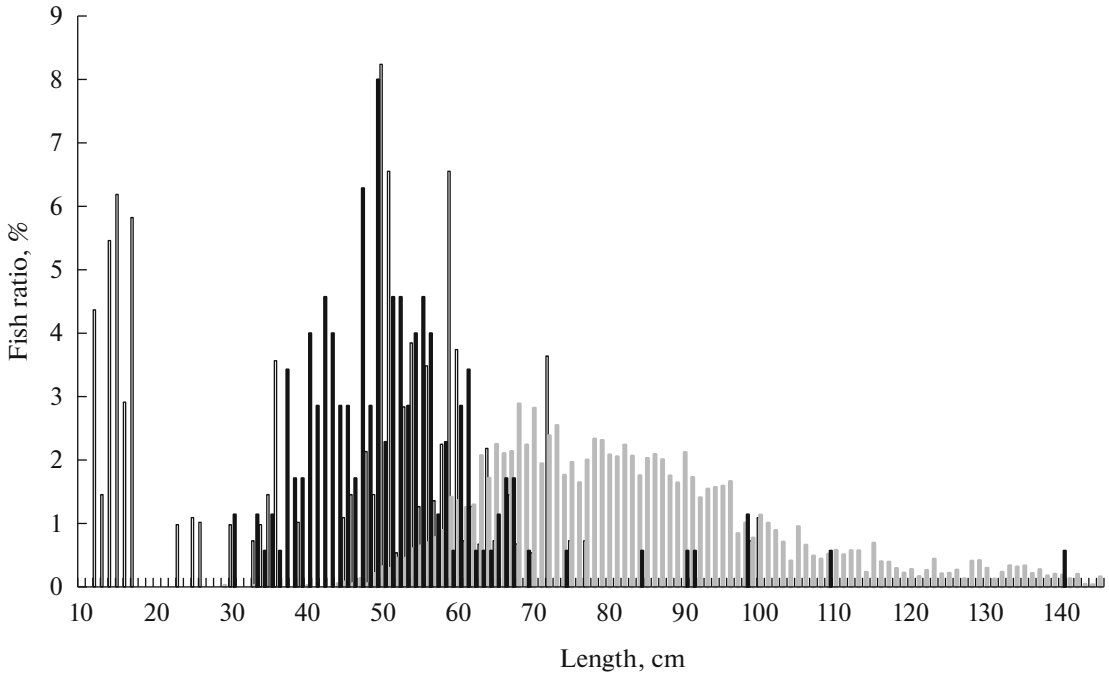

Fig. 1. Size structure (*FL*) of the Pacific halibut *Hippoglossus stenolepis* in the catches of different fishing gear in Olyutorsky-Navarin region of the Bering Sea in 1995–2015: (□) bottom trawl (M = 43.6 cm, n = 3624 ind.), (▨) setline (M = 83.2 cm, n = 3375 ind.), (■) snurrevad (M = 51.5 cm, n = 175 ind.).

10-year old specimens dominate, and their ratio exceeds 80% (Datsky and Andronov, 2007). According to the data of snurrevad catches, mostly immature specimens *FL* 30–69 cm at the age 5–9 years grow here, while larger fish (up to 145 cm) are observed from time to time (Figs. 2a and 2c). Larger specimens of the Pacific halibut (*FL* 44–145 cm, age classes 4+–22+) were registered in the setlines, and approximately 60% were the specimens *FL* 63–90 cm (Figs. 2a–2e). The exclusively large specimens *FL* 85–115 cm at the age 7–13 years are caught by setlines at the depths of 7–30 m along the whole Koryak coast (Chikilev, 1998; Chikilev and Pal'm, 1999). Taking into account the catches of mostly immature specimens of halibut by the active fishing gear, the catching volume of this species is small and frequently occasional, so the setline is the most rational fishing gear that takes the mature specimens of this species. This is conveniently illustrated by the average body size of the Pacific halibut in the catches performed by different fishing gear: in setlines and bottom gill nets, the specimens are significantly larger than those caught by the trawls and snurrevads (Table 1).

During the first years of life of halibut, the weight gain is lower than the linear growth: the body weight of young specimens *FL* < 40 cm does not exceed 0.5 kg, but the fish *FL* 49–60 cm reach the body weight 1.5–2.5 kg (Fig. 3). Later, body weight increases significantly: body weight of fish *FL* > 90 cm usually exceeds 10 kg; for example, in halibuts *FL* 99, 110, and 133 cm, this parameter was 14.2, 17.0, and 29.5 kg, respectively. The average weight gain per 1-cm growth (body length) varies as 0.2–0.5 kg (Fadeev, 2005). The females are larger than males in each age class; in some cases, this difference reaches 30 cm (Datsky and Andronov, 2007).

In the Pacific halibut, the dependence of body weight (W, g) on the body length (*FL*, cm) is described by the following equations: in the bottom trawls, $W = 0.009\ FL^{3.068}$ (r = 0.96, n = 139 ind.); in snurrevads, $W = 0.0079\ FL^{3.0734}$ (r = 0.97, n = 211 ind.); in the setlines, $W = 0.0073\ FL^{3.0935}$ (r = 0.98, n = 207 ind.); in the stab nets, $W = 0.0047\ FL^{3.2051}$ (r = 0.98, n = 60 ind.).

The size spectra and the sex ratio of the Pacific halibut change significantly in accordance to the depth. In the setline catches (Chikilev, 1998; Chikilev and Pal'm, 1999), mostly large females *FL* 85–115 cm remain during the summer period at the depths of 5–30 m; female : male ratio is 7.6 : 1.0. In the meantime, mostly immature specimens were registered in the trawl catches performed at the depth of less than 50 m (Fig. 4). At the depths of 50 m and more, the size of the fish decreases; most of the specimens were *FL* 40–80 cm; male abundance exceeded the female abundance 1.5–3.0 times. In the waters of the outer shelf and the continental slope, the sex ratio has changed again, when the females dominated (1.0 : 0.7), and the ratio of large fish increased. We argue on the separate distribution of the males and females of the Pacific halibut during the growing period.

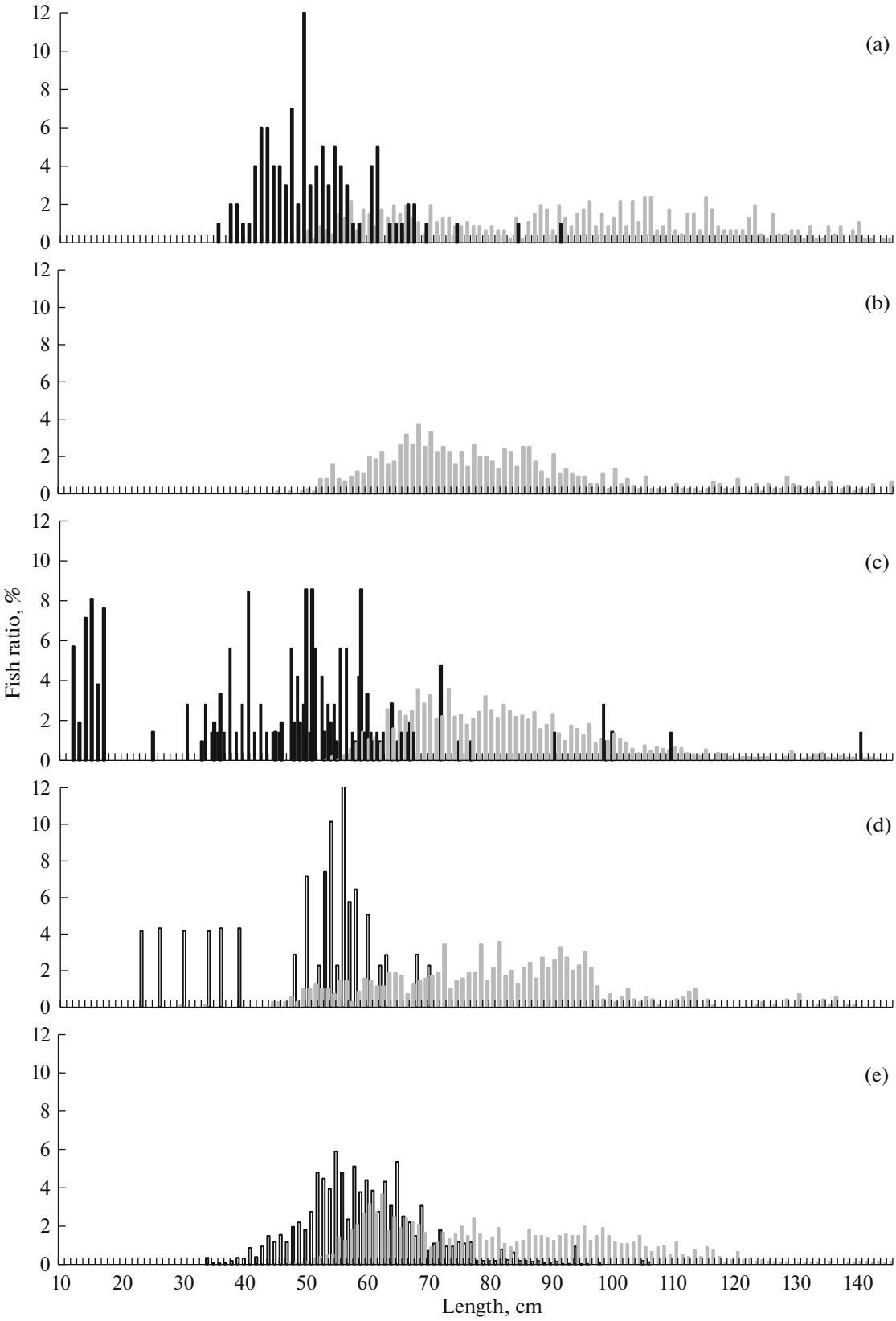

Fig. 2. Size structure (*FL*) of the Pacific halibut *Hippoglossus stenolepis* in the catches of the bottom trawls, setlines, and snurrevads in Olyutorsky-Navarin region of the Bering Sea: (a) 1997 (setline) and 1998 (snurrevad), (b) 1999, (c) 2000 (setline, snurrevad) and 2004 (trawl), (d) 2005, (e) 2012 (trawl) and 2015 (setline); refer to Fig. 1 for the keys.

Table 1. Body length, body weight, and the sex ratio of the Pacific halibut *Hippoglossus stenolepis* in the catches in Olyutorsky-Navarin region of the Bering Sea

Study period (month, year)	Number of fish, ind.	Length (*FL*), cm			Weight, kg			Female : male ratio
		females	males	both sexes	females	males	both sexes	
Bottom trawl, mesh size in the cod end 10–12 mm								
Aug.–Sept. 1999	103	63.2	63.8	63.5	3.950	3.772	3.865	1.1 : 1.0
Aug.–Sept. 2001	44	63.4	59.8	61.0	5.500	2.798	4.182	1.2 : 1.0
Sept.–Oct. 2001	27	56.0	55.6	55.9	2.193	2.224	2.215	0.4 : 1.0
Oct.–Nov. 2004	61	58.3	50.5	57.5	3.600	2.600	3.425	0.9 : 1.0
Aug.–Sept. 2005	29	–	–	59.0	–	–	1.573	–
July–Aug. 2012	376	–	–	59.9	–	–	2.730	0.8 : 1.0
Bottom trawl, mesh size in the cod end 60 mm								
Oct. 2008	511	64.8	65.0	64.6	4.138	4.458	3.925	0.7 : 1.0
Oct. 2014	140	63.0	65.0	60.9	4.000	5.104	3.413	0.8 : 1.0
Snurrevad, mesh size 35–40 mm								
Aug.–Sept. 1998	104	63.0	51.2	51.6	2.819	1.595	1.642	0.1 : 1.0
July–Aug. 2000	71	56.5	48.9	52.6	2.493	1.441	1.956	1.0 : 1.0
Setline								
July–Oct. 1997	647	99.4	75.1	90.3	11.979	4.488	8.251	1.7 : 1.0
July–Sept. 1999	794	100.1	74.6	86.9	–	–	7.300	2.7 : 1.0
July–Sept. 2000	321	101.9	82.1	94.6	8.644	6.260	7.503	1.5 : 1.0
Aug.–Sept. 2005	46	83.2	79.1	81.1	9.919	8.835	9.377	1.0 : 1.0
June–July 2015	176	99.0	70.3	81.6	–	–	–	4.0 : 1.0
Stab nets, mesh size 115 mm								
July 1997	60	78.9	76.1	77.4	7.111	5.345	6.140	0.8 : 1.0

Males of the Pacific halibut mature at the age 4–10 years (*FL* 50–100 cm), and females mature at 6–14 years (*FL* 60–140 cm). En masse, the males mature at 8–9 years (*FL* 75 cm), and females at 9–11 years, *FL* 95 cm (Novikov, 1974; Fadeev, 2005).

The reproduction of the Pacific halibut along the Asian shores is scarcely studied. It was reported that this species spawned in autumn–winter period (October–February) outside the continental shallows, at the slopes of the deeps and trenches of more than 500 m depth at the water temperature of 2.3–3.5°C in the near-bottom layer (Novikov, 1974). In the trawl catches, most of the fish carried gonads of stage II of maturation (Table 2). However, due to the dominance of the immature specimens in this fishing gear, these data can be hardly used for the clarification of the dates of the seasonal maturation of the species. For example, when catching the mature specimens by the setline in August, up to 44% of females were characterized by the gonads of stage IV, while 40% of males by stage III–IV (Chikilev and Pal'm, 1999). The maximal density of the halibut eggs (up to 14 egg/m^2) was registered along the Koryak coast in the pelagial at the depths down to 400 m (Pertseva-Ostroumova, 1961), and the larvae of 34–42-mm length were found at the depths of 7–43 m (Musienko, 1957).

Greenland halibut *Reinhardtius hippoglossoides* reaches 21–24 years, *FL* 130 cm, and body weight 18 kg in the Pacific Ocean (Novikov, 1974; Novikov et al., 1992; Naumenko and Davydov, 2003). The immature specimens *FL* < 35 cm at the age of up to 4–5 years dominate at the depths of less than 200 m both in winter and in summer periods. Usually, the rate of the large fish increases in regard to the depth. At the depths exceeding 300 m, the specimens *FL* > 40–45 cm dominate in the trawl catches (Shuntov, 1971; Fadeev, 1987). In trawls, the size of the Greenland halibut is usually smaller compared to that in the passive fishing gear (bottom setline and gill nets). The size spectra of the fish in the last two types of gear may be regulated by using the mesh of different diameter (Kodolov and Savin, 1998).

In Olyutorsky-Navarin region in the summer–autumn period, the Greenland halibut *FL* 7–100 cm

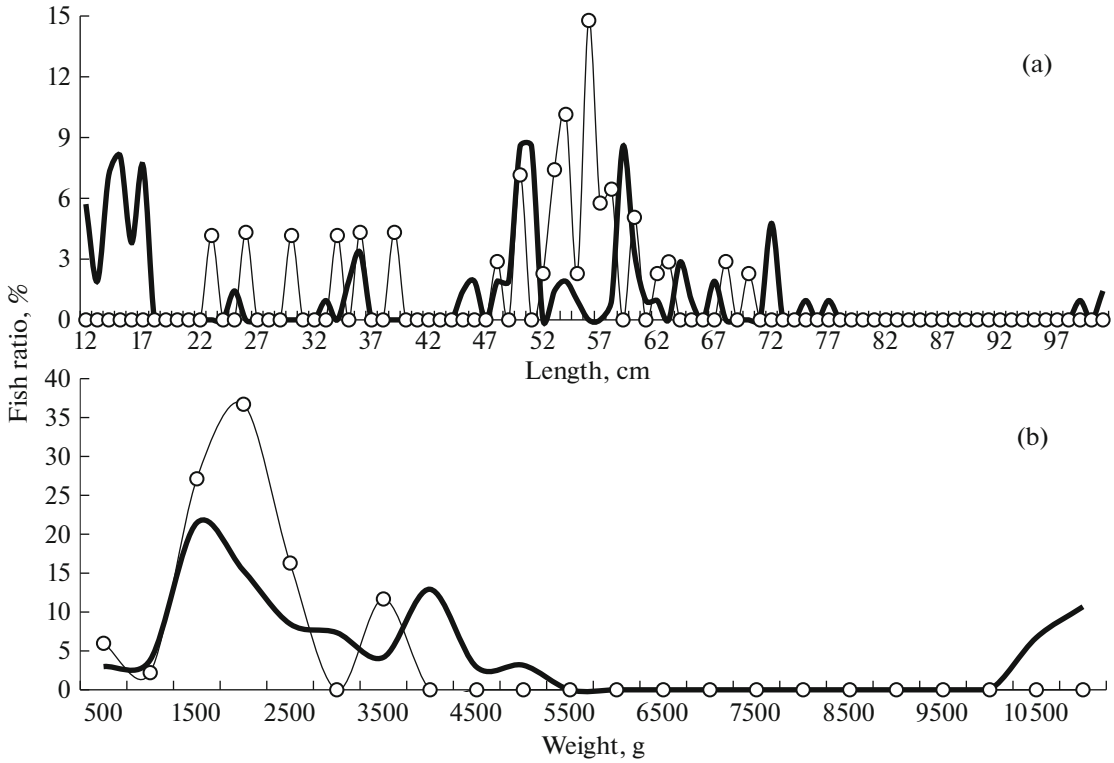

Fig. 3. Size structure (*FL*) and weight spectra of the Pacific halibut *Hippoglossus stenolepis* in Olyutorsky-Navarin region according to the trawl catches in 2004 (▬) and 2005 (—○—): (a) body length (2004: $M = 41.7$ cm, $n = 55$ ind.; 2005: $M = 49.9$ cm, $n = 29$ ind.), (b) body weight (2004: $M = 1495$ g, $n = 55$ ind.; 2005: $M = 1573$ g, $n = 29$ ind.).

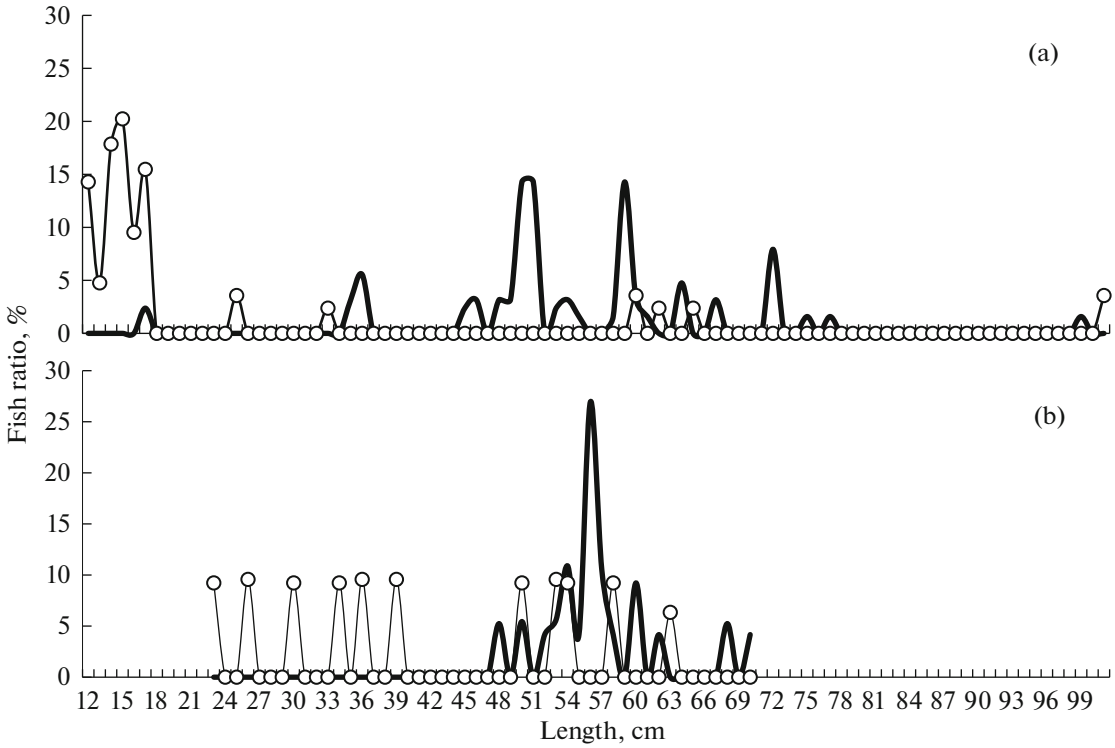

Fig. 4. Size structure (*FL*) of the Pacific halibut *Hippoglossus stenolepis* in Exclusive Economic Zone (▬) and territorial waters (—○—) of Olyutorsky-Navarin region according to the trawl catches: (a) 2004 (EEZ: $M = 54.5$ cm, $n = 33$ ind.; territorial waters: $M = 22.5$ cm, $n = 22$ ind.), (b) 2005 (respectively, $M = 56.7$ cm, $n = 16$ ind.; $M = 41.7$ cm, $n = 13$ ind.).

Table 2. Gonad ratio of the Pacific halibut *Hippoglossus stenolepis* in Olyutorsky-Navarin region of the Bering Sea in June–November, %

Month, year	Sex	Stage of gonad ripeness					Number of fish, ind.
		II	III	IV	V	VI–II	
Aug.–Sept. 1999	Females	94.4	1.9	3.7	0	0	54
	Males	81.6	10.2	6.1	0	2.0	49
Sept.–Oct. 2001	Females	100	0	0	0	0	8
	Males	94.4	5.6	0	0	0	18
Aug. 2002	Females	100	0	0	0	0	3
	Males	14.3	85.7	0	0	0	7
Oct.–Nov. 2004	Females	100	0	0	0	0	30
	Males	87.5	0	12.5	0	0	32
Oct. 2014	Females	96.5	0	3.5	0	0	65
	Males	66.2	29.6	4.2	0	0	75
June–July, 2015	Females	79.0	18.0	3.0	0	0	150
	Males	77.0	23.0	0	0	0	26

(age 1–16 years) was found in the trawl catches, and the fish of the size groups of 7–9, 12–15, 19–23, 33–36, and 40–45 cm dominated (Figs. 5, 6), which referred to the ages 0+, 1+, 2+, 3+, and 4+–5+. Taking into account the maturation of this species at *FL* 42–52 cm (Fadeev, 2005), we state that the trawl catches were presented by mostly immature specimens, because the rate of the fish *FL* > 40 cm did not exceed 15%. In the meantime, the trawl catches allow particularly assessing the ratio of the generations. For example, in 2001–2005, the generations of 1999–2001 were the most abundant (Figs. 6c–6f). Regard must be paid to approximately 90% of the young specimens of the Greenland halibut in the Bering Sea gathering northwards 58° N (Alton et al., 1988), and the fish of the age 0+ and 1+ are found mostly in the Gulf of Anadyr (Kodolov and Matveychuk, 1994). The generation of 1999 was particularly characterized by the high abundance in the catches in the Gulf of Anadyr even in 1999 (young-of-the-year *FL* ≤ 10 cm), and then it formed the bulk of the trawl catches during the next years in Olyutorsky-Navarin region.

Larger Greenland halibut specimens *FL* 45–105 and 58–104 cm at the age 7–17 years were caught by the setlines and nets; specimens *FL* 70–93 cm, mode 80–89 cm (12–14 years) comprised more than 70% of the catch (Figs. 6a–6c and 6f). Therefore, as was proposed for the Pacific halibut, the setline and nets are the most rational fishing gear that takes the mature specimens of significantly larger body size compared to the trawl (Table 3).

In general, in the Bering Sea, the body length of the Greenland halibut in the net catches exceeds that of the specimens of the western Kamchatka (Kodolov and Savin, 1998; Kupriyanov and Davydov, 1998) and eastern Sakhalin (Kim Sen Tok and Biryukov, 1998) by approximately 5–10 cm. In the trawl catches, its body length also exceeds that of the specimens of eastern Sakhalin, western Kamchatka, and the central Sea of Okhotsk by 3–5 cm (Novikov, 1974; Vatulina, 1992; Kim Sen Tok and Biryukov, 1998).

The weight gain and the body length increase in the Greenland halibut is a relatively rapid process, but it is slower compared to the other halibuts and some large species of Pleuronectidae (Fadeev, 2005). The fish length and weight may be corresponded to each other easily in Fig. 7: the specimens *FL* 36 cm (3+) are approximately 0.4 kg; 40 cm (4+), 0.6 kg; 44–47 cm (5+), 0.8 kg; 48–52 cm (6+–7+), 1.1 kg; etc. As the body length of the Greenland halibut increases by 5 cm, its body weight gains 0.3–1.0 kg, and reaches even 14.4 kg in the specimens *FL* 100 cm. The body length of females exceeds that in the males of the same age group by 3–7 cm.

In the Greenland halibut, the dependence of body weight on the body length is described by the following equations: in the bottom trawls, $W = 0.0014\ FL^{3.4654}$ ($r = 0.99$, $n = 422$ ind.); in the setlines, $W = 0.0051\ FL^{3.1579}$ ($r = 0.97$, $n = 247$ ind.); in the stab nets, $W = 0.0024\ FL^{3.3182}$ ($r = 0.96$, $n = 50$ ind.).

In the net catches, the body length of the Greenland halibut depends on the sampling depth; this may be explained by the separation of the males and

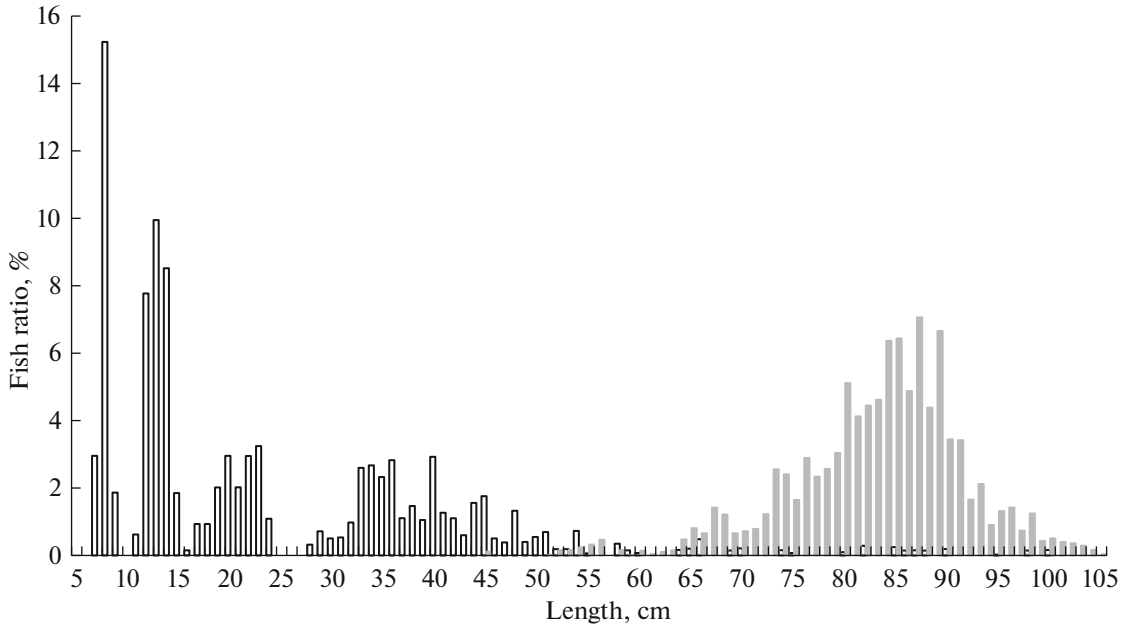

Fig. 5. Size structure (*FL*) of the Greenland halibut *Reinhardtius hippoglossoides* in Olyutorsky-Navarin region of the Bering Sea in 1995–2015 in the catches of the bottom trawls ($M = 23.8$ cm, $n = 363$ ind.) and setlines ($M = 83.0$ cm, $n = 5304$ ind.); refer to Fig. 1 for the keys.

females in regard to the depth. The females are characterized by larger body length (81–85 cm), they prefer to remain at the depths of less than 400 m; their abundance exceeds that of males fourfold. At the depths of 400 m and more, the males' abundance (*FL* 68–73 cm) increases by 2.4 times (Pal'm et al., 1999). In general, the immature specimens in the study area avoid the coastal areas of the shelf; insignificant catches of the fish *FL* 30–48 cm were registered in particular years (Fig. 8). Smaller specimens prefer the shallow Gulf of Anadyr, as was mentioned above.

The Bering Sea population of the Greenland halibut is characterized by the age of maturation of 5–10 years at *FL* 50–80 cm (Novikov, 1974; D'yakov, 1982, 2011). Females mature at *FL* 42–61 cm, males, at *FL* 52–72 cm, and the maturation en masse (50%) is registered for 51 cm (4–5-year old) and 61 cm (6–7-year old), respectively (Fadeev, 2005).

Major spawning grounds of the Greenland halibut in the Bering Sea are located between the Unimak Pass and Pribilof Islands (Alton et al., 1988). Spawning is reported also for the northwestern Bering Sea: along Koryak coast, in the southern part of the Gulf of Anadyr, between Navarin Island and St. Matthew Island at the depth range of 100–680 m at the water temperature of 1.0–3.5°C (Novikova, 1974). The Greenland halibut spawns in autumn–winter period with the peak in October–December in the western Bering Sea (Fadeev, 1987). Actually, in August–October, most of the fish were characterized by gonad states II and III; however, in particular years, up to 40% of females and up to 34% of males were at a prespawning state (Table 4). It was reported earlier (Pal'm et al., 1999) that there were the prespawning and spawning specimens in Olyutorsky-Navarin region in November–December 1994–1995. The eggs develop in the pelagial at the depths of 550 m and deeper; the larvae are transported to the shallower areas as they grow. The juveniles *FL* 59.0–64.6 mm distribute in the southern Gulf of Anadyr at the depths of 18–40 m (Musienko, 1957).

Alaska plaice *Pleuronectes quadrituberculatus* belongs to the large flounder species; oftentimes, its body length and body weight in the Bering Sea exceed 60 cm and 3.5 kg (Fadeev, 1971, 1987, 2005). In the northwestern Bering Sea, this species reaches *FL* 66 cm and body weight 3.75 kg at the maximum age 30 years. The mature specimens dominate in the catches: *FL* 25–51 cm and body weight 0.3–1.4 kg at the age 8–17 years (Datsky and Andronov, 2007).

In Olyutorsky-Navarin region, in trawl catches, the Alaska plaice specimens *FL* 10–62 cm and body weight 0.08–3.40 kg were found. The fish *FL* 21–33 cm, mode 22–26 cm (more than 74% by abundance), dominated in the catches (Fig. 9). Larger plaice (*FL* 19–65 cm, dominant group *FL* 35–48 cm (approximately 72%), mode 40–43 cm) prevailed in snurrevads, and the immature specimens *FL* < 19 cm were absent in this fishing gear, although they were present in the trawls as insignificant size group (*FL* 10–18 cm, 4.4%). Their absence in snurrevads (due to the selective catch efficiency) leads to the larger average size of the specimens in this type of the fishing gear (Table 5).

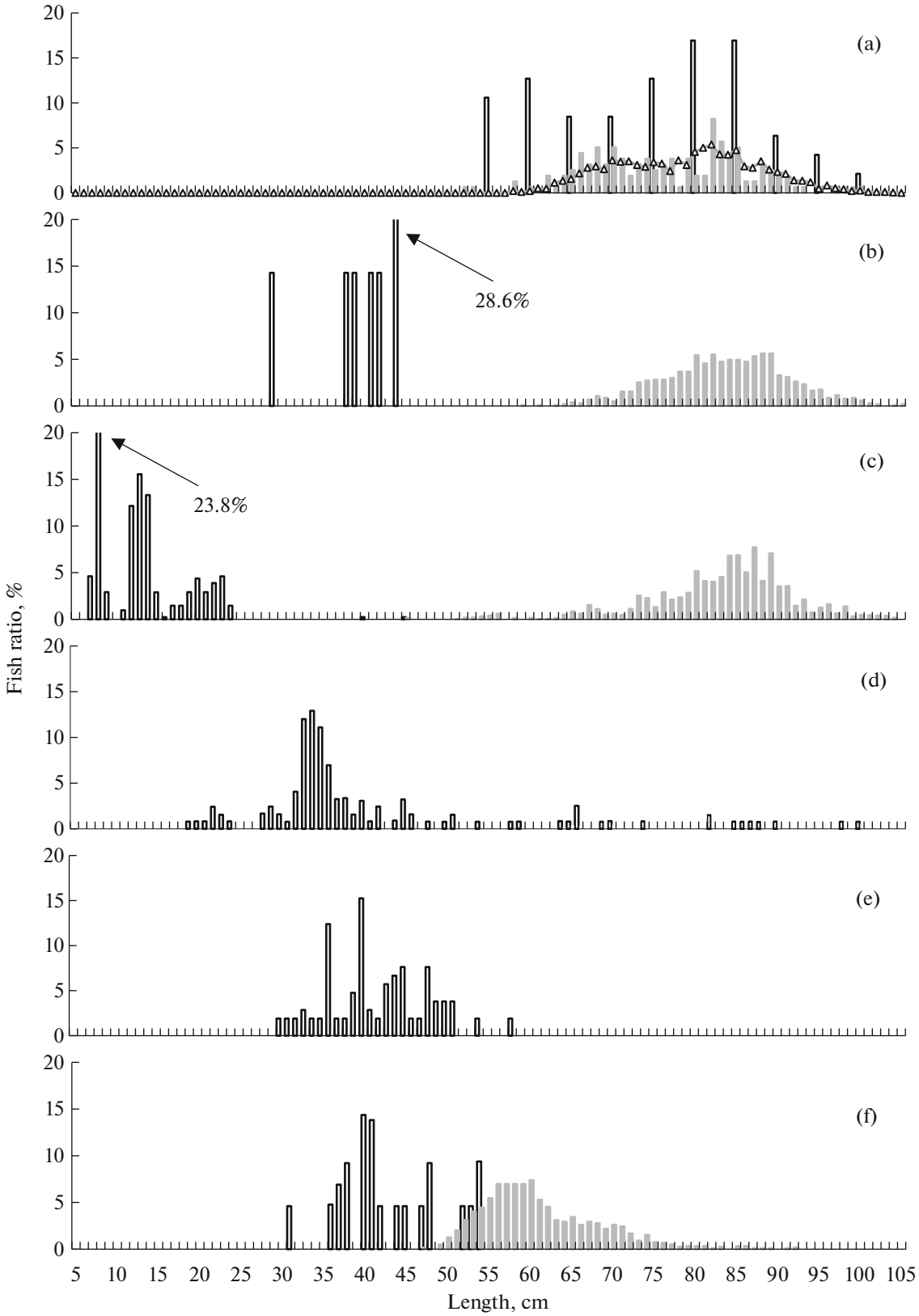

Fig. 6. Size structure (*FL*) of the Greenland halibut *Reinhardtius hippoglossoides* in the catches of the bottom trawls, setlines, and nets in Olyutorsky-Navarin region of the Bering Sea in different years: (a) 1996 (trawl) and 1997 (setline, nets), (b) 1999, (c) 2000 (setline) and 2001 (trawl), (d) 2002, (e) 2004, (f) 2005 (trawl) and 2015 (setline); (−Δ−) stab nets, refer to Fig. 1 for the keys.

Table 3. Body length, body weight, and the sex ratio of the Greenland halibut *Reinhardtius hippoglossoides* in the catches in Olyutorsky-Navarin region of the Bering Sea

Study period (month, year)	Number of fish, ind.	Length (*FL*), cm			Weight, kg			Females : males ratio
		females	males	both sexes	females	males	both sexes	
Bottom trawl, mesh size in the cod end 10–12 mm								
Sept. 1996	108	75.0	62.4	70.8	5.401	2.429	4.410	2.0 : 1.0
Aug.–Sept. 1999	206	67.1	50.5	58.1	4.191	1.348	2.699	1.1 : 1.0
Sept.–Oct. 2001	19	70.3	40.8	57.9	4.570	0.904	3.026	1.4 : 1.0
Aug. 2002	89	50.7	39.4	44.1	2.274	0.674	1.339	0.7 : 1.0
Oct.–Nov. 2004	46	41.2	41.9	41.6	0.459	0.541	0.552	0.8 : 1.0
Aug.–Sept. 2005	21	–	–	43.2	–	–	0.603	0.8 : 1.0
July–Aug. 2012	208	–	–	42.3	–	–	0.586	0.8 : 1.0
Bottom trawl, mesh size in the cod end 60 mm								
Oct. 2008	39	64.5	65.1	63.0	2.517	2.605	2.275	2.7 : 1.0
Oct. 2014	24	51.8	55.9	47.2	1.683	2.262	1.046	1.1 : 1.0
Setline								
July–Oct. 1997	97	–	–	76.4	–	–	4.710	–
July–Sept. 1999	154	–	–	83.3	–	–	5.692	8.0 : 1.0
July–Sept. 2000	247	83.7	66.7	81.1	6.469	3.018	5.926	5.3 : 1.0
June–July 2015	100	69.8	59.5	61.2	3.634	1.939	2.888	1.4 : 1.0
Stab nets, mesh size 115 mm								
July 1997	175	83.0	72.5	81.3	6.007	3.475	5.602	5.3 : 1.0

The size spectra of the Alaska plaice may vary greatly from year to year due to the dominating of the particular generations (Fig. 10). For example, the specimens *FL* < 28 cm were not found in the trawl catches in 1999 and 2001; the fish *FL* 37–45 and 36–42 cm (11–16-year old) dominated, respectively (Figs. 10b and 10c). On the other hand, in 1996 and 2005, the plaice *FL* 27–35 cm at the age 9–14 years (Figs. 10a and 10e) were the dominating group; in 2004, even smaller fish (*FL* 21–28 cm at the age 8–10 years) made the most of the catch (Fig. 10d). Trawling in the shallow shelf areas, where the young specimens school at the depths of less than 70 m, plays a great role in obtaining these results (Datsky and Andronov, 2007).

A significant weight gain in regard to the linear growth is a feature of the Alaska plaice compared to the other plaice species. The weight gain is 75 g per each 2 cm of the body length increase in the specimens *FL* 28–34 cm, while it is by 140–170 g in larger specimens (Fadeev, 1987). In the study area, the increase of the average body length by 5.7 cm (Fig. 11a) refers to the weight gain of 289 g (Fig. 11b) or by 51 g per 1 cm. In the size groups of 21–30, 31–40, 41–50 cm, and ≥ 51 cm, the weight gain by 1 cm was 24, 49, 109, and 198 g, respectively.

In the Alaska plaice, the dependence of body weight on the body length is described by the following equations: in the bottom trawls, $W = 0.007\ FL^{3.188}$ ($r = 0.98$, $n = 340$ ind.); in snurrevads, $W = 0.0185\ FL^{2.9003}$ ($r = 0.90$, $n = 326$ ind.).

The average size-weight parameters of the females of the Alaska plaice are higher compared to those in males; usually, the largest specimens were the females. Generally, in the study area, the difference between the females and males in the catches of the bottom trawl and snurrevad was, on average, 5.8 and 5.6 cm, and 0.57 and 0.25 kg, respectively. In general, females' abundance exceeded that of males (Table 5).

The maximal abundance of the young specimens of the Alaska plaice *FL* < 24 cm at the age 6–8 years at the western part of the Gulf of Anadyr and at the Koryak shelf was reported earlier (Datsky and Andronov, 2007). At Koryak shelf, the rate of the large specimens (age 15 years and older) increased in regard to the depth increase, the young specimens and the fish that matured for the first time preferred the coastal waters (Fig. 12).

The Alaska plaice is a late maturing fish species. In the eastern Bering Sea, the males and females mature en masse at *FL* 23.4 and 28.4 cm, respectively (Fadeev, 1987). In the northwestern Bering Sea, the females

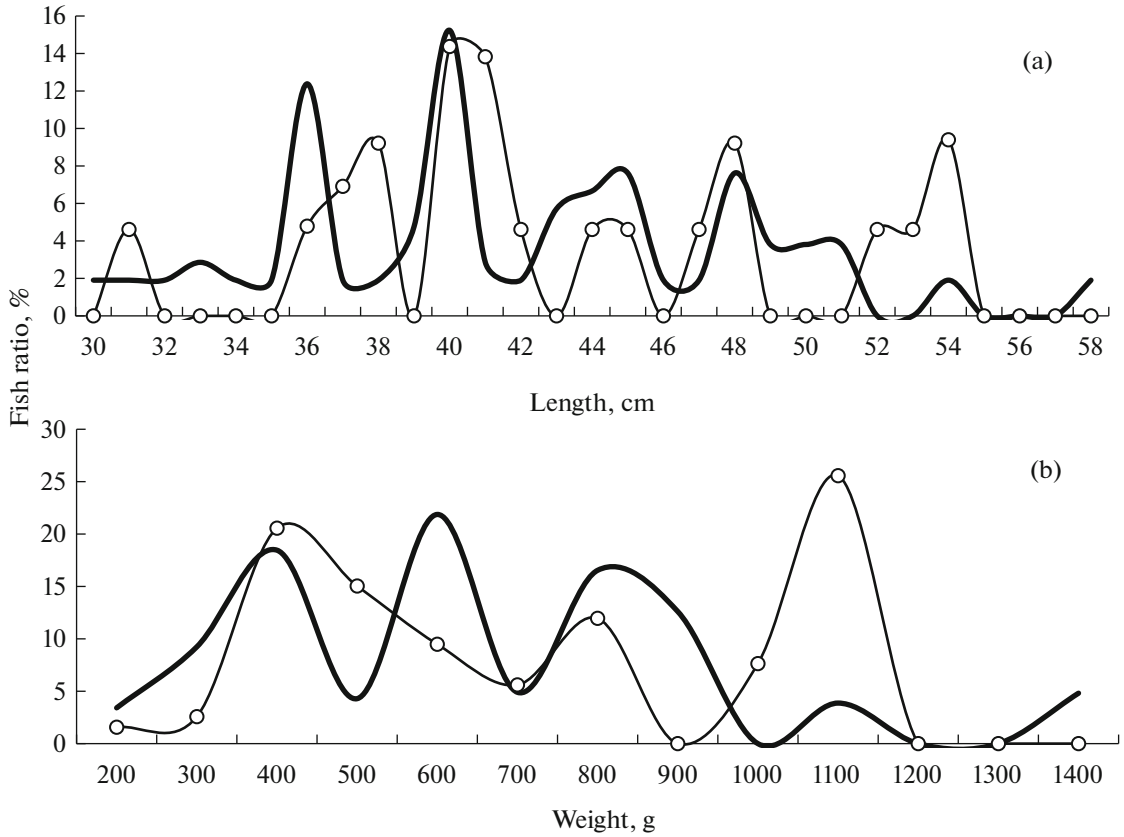

Fig. 7. Size structure (*FL*) and weight spectra of the Greenland halibut *Reinhardtius hippoglossoides* in Olyutorsky-Navarin region, according to the trawl catches in 2004 and 2005: (a) body length (2004: $M = 41.9$ cm, $n = 46$ ind.; 2005: $M = 43.2$ cm, $n = 21$ ind.), (b) body weight (2004: $M = 552$ g, $n = 46$ ind.; 2005: $M = 603$ g, $n = 21$ ind.); refer to Fig. 3 for the keys.

mature en masse at *FL* 27–30 cm at the age 6–8 years (V.V. Bazuev and S.A. Pal'm, personal communication). The growth rate in males slows down after they reached maturation opposite to that in females (Fadeev, 1987).

In the northwestern Bering Sea, the Alaska plaice spawns in May–June at 180–200-m depth. The eggs are laid both near the bottom at the temperature of –1.7 to 1.4°C and in the surface water layers at the temperature of –1.5 to 3.1°C (Fadeev, 1987). The recent spawning of this species in Olyutorsky-Navarin region may be tracked by the data of 1999, when the gonads of more than 40% of females were at a postspawning state in August–September. In summer–autumn period, most specimens were characterized by the gonads of state II and III; males usually matured earlier than females (Table 6).

The maximal egg density (up to 217 egg/m^2) was registered in the southwestern Gulf of Anadyr above the depths of 85–134 m; the near-bottom water temperature was 1.5–1.7°C. The egg density along the Koryak coast is minimal; it reached 23 egg/m^2 only in the area of Natalia Bay. The larvae of 5.9–6.5-mm length distribute in the areas of spawning or around them at the depths of 71–99 m; the juveniles of 5.8–8.7-cm length keep in the bays and inlets at the depths of 9–10 m (Pertseva-Ostroumova, 1961).

The northern rock sole *Lepidopsetta polyxystra* is a large flounder species: in the Bering Sea, *FL* reaches 69 cm, 2.3 kg body weight, and 20 years (Fadeev, 1971, 1987, 2005). This species has a middle position between the abundant plaice species of the northwestern Bering Sea: it is larger than flat-headed flounders but smaller than the Alaska plaice. In the catches, the specimens *FL* 9–57 cm are found, while the mature specimens (*FL* 29–40 cm, 0.3–0.8 kg body weight, 10–14 years) dominate (Datsky and Andronov, 2007).

In the trawl catches obtained in Olyutorsky-Navarin region, the major group were the growing specimens *FL* 10–53 cm and body weight 0.009–2.730 kg. The specimens *FL* 25–41 cm (approximately 82% by abundance), mode 30–33 cm, dominated (Fig. 13). The ratio of the immature specimens *FL* < 25 cm was, on average, 10.1%, but it varied greatly from year to year. In 1996–2001, the ratio of this group in the catches was 25.2–38.4% (Figs. 14a and 14b), but only 0.8–7.6% in 2002–2005 (Figs. 14c–14e). Such a decrease of the number of recruitment is probably explained by the unfavorable conditions for reproduction if we take into account the detailed study of the

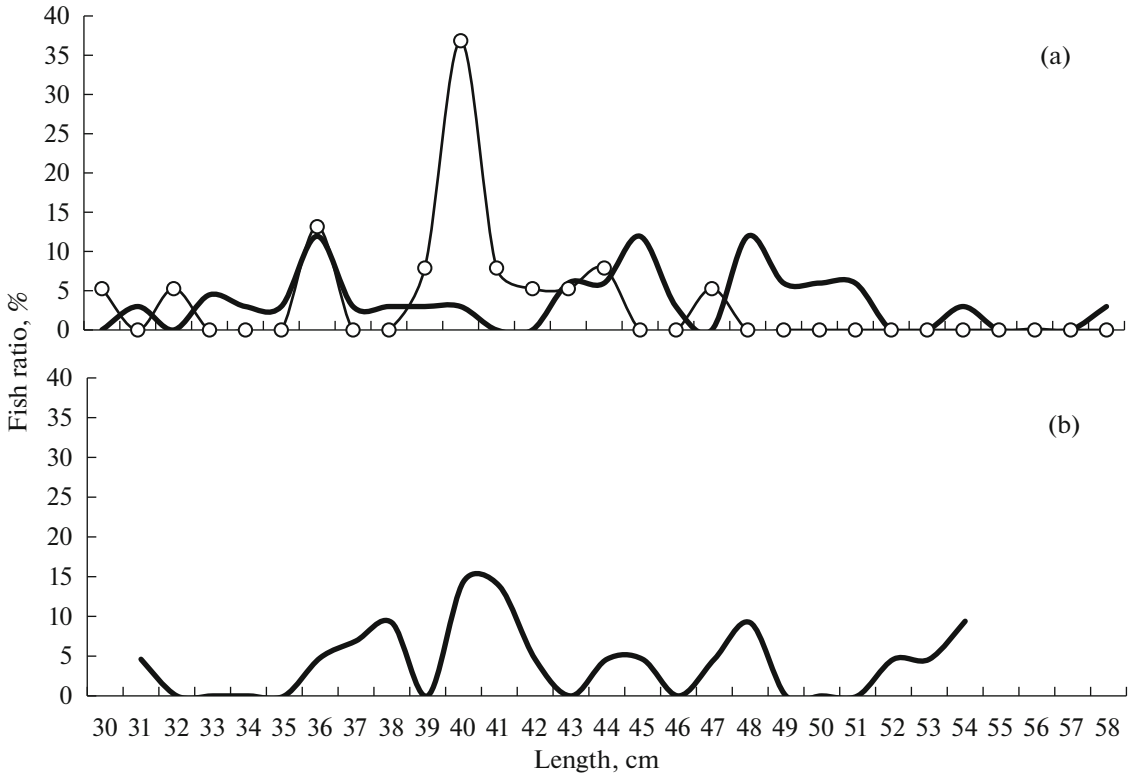

Fig. 8. Size structure (*FL*) of the Greenland halibut *Reinhardtius hippoglossoides* in Exclusive Economic Zone and territorial waters of Olyutorsky-Navarin region according to the trawl catches: (a) 2004 (EEZ: $M = 43.3$ cm, $n = 29$ ind.; territorial waters: $M = 39.5$ cm, $n = 17$ ind.), (b) 2005 (EEZ: $M = 43.2$ cm, $n = 21$ ind.); refer to Fig. 4 for the keys.

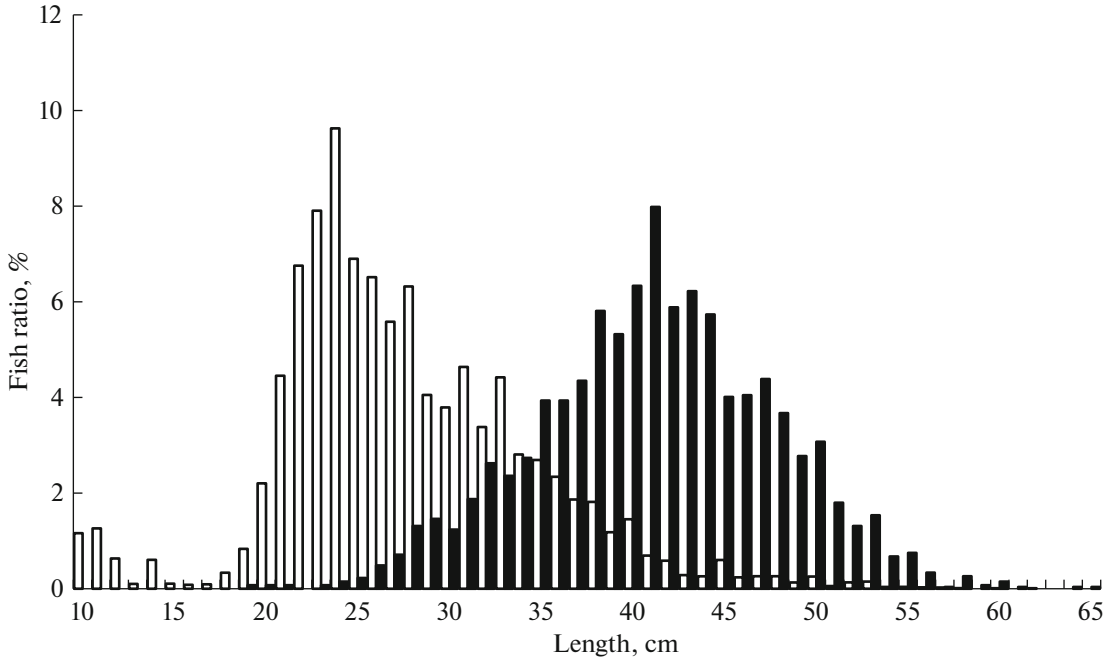

Fig. 9. Size structure (*FL*) of the Alaska plaice *Pleuronectes quadrituberculatus* in Olyutorsky-Navarin region of the Bering Sea in 1995–2015 in the catches of the bottom trawls ($M = 27.7$ cm, $n = 2087$ ind.) and snurrevads ($M = 41.1$ cm, $n = 2668$ ind.); refer to Fig. 1 for the keys.

Table 4. Gonad ratio of the Greenland halibut *Reinhardtius hippoglossoides* in Olyutorsky-Navarin region of the Bering Sea in June–November, %

Month, year	Sex	Stage of gonad ripeness					Number of fish, ind.
		II	III	IV	V	VI–II	
Aug.–Sept. 1996	Females	51.5	13.2	35.3	0	0	68
	Males	54.3	11.4	34.3	0	0	35
Aug.–Sept. 1999	Females	48.0	12.0	35.0	4.0	1.0	100
	Males	76.5	9.2	14.3	0	0	98
Sept.–Oct. 2001	Females	63.6	9.1	9.1	0	18.2	11
	Males	62.5	25.0	0	12.5	0	8
Aug. 2002	Females	75.7	24.3	0	0	0	37
	Males	88.5	11.5	0	0	0	52
Oct.–Nov. 2004	Females	92.6	7.4	0	0	0	27
	Males	100	0	0	0	0	36
Oct. 2008	Females	91.0	9.0	0	0	0	25
	Males	78.0	22.0	0	0	0	14
Oct. 2014	Females	82.0	18.0	0	0	0	14
	Males	71.0	29.0	0	0	0	10
June–July 2015	Females	39.0	45.0	16.0	0	0	56
	Males	73.0	27.0	0	0	0	44

Table 5. Body length, body weight, and the sex ratio of the Alaska plaice *Pleuronectes quadrituberculatus* in the catches in Olyutorsky-Navarin region of the Bering Sea

Study period (month, year)	Number of fish, ind.	Length (*FL*), cm			Weight, kg			Females : males ratio
		females	males	both sexes	females	males	both sexes	
	Bottom trawl, mesh size in the cod end 10–12 mm							
Sept. 1996	24	37.9	32.3	36.0	0.869	0.495	0.745	2.0 : 1.0
Aug.–Sept. 1999	158	44.6	38.7	41.8	1.430	0.740	1.102	1.1 : 1.0
Sept.–Oct. 2001	102	39.6	36.9	38.0	1.147	0.757	0.918	0.7 : 1.0
Aug. 2002	60	48.7	39.9	43.4	1.861	0.845	1.251	0.7 : 1.0
Aug.–Sept. 2003	150	44.6	39.4	42.0	1.178	0.726	0.949	1.0 : 1.0
Oct.–Nov. 2004	626	24.9	24.6	24.8	0.870	0.368	0.712	1.2 : 1.0
Aug.–Sept. 2005	53	42.4	30.6	36.2	–	–	0.780	0.7 : 1.0
July–Aug. 2008	1087	41.3	35.9	37.2	–	–	0.889	0.9 : 1.0
July–Aug. 2012	57	–	–	35.2	–	–	0.715	1.4 : 1.0
	Snurrevad, mesh size 35–40 mm							
Aug.–Sept. 1998	50	41.3	35.4	37.3	0.932	0.556	0.677	0.5 : 1.0
July–Sept. 1999	76	45.6	40.0	43.5	1.261	0.645	1.026	1.6 : 1.0
July–Aug. 2000	200	45.1	39.3	42.7	1.330	0.820	1.120	1.4 : 1.0
Aug.–Sept. 2005	150	44.6	39.4	42.0	1.178	0.726	0.949	1.0 : 1.0

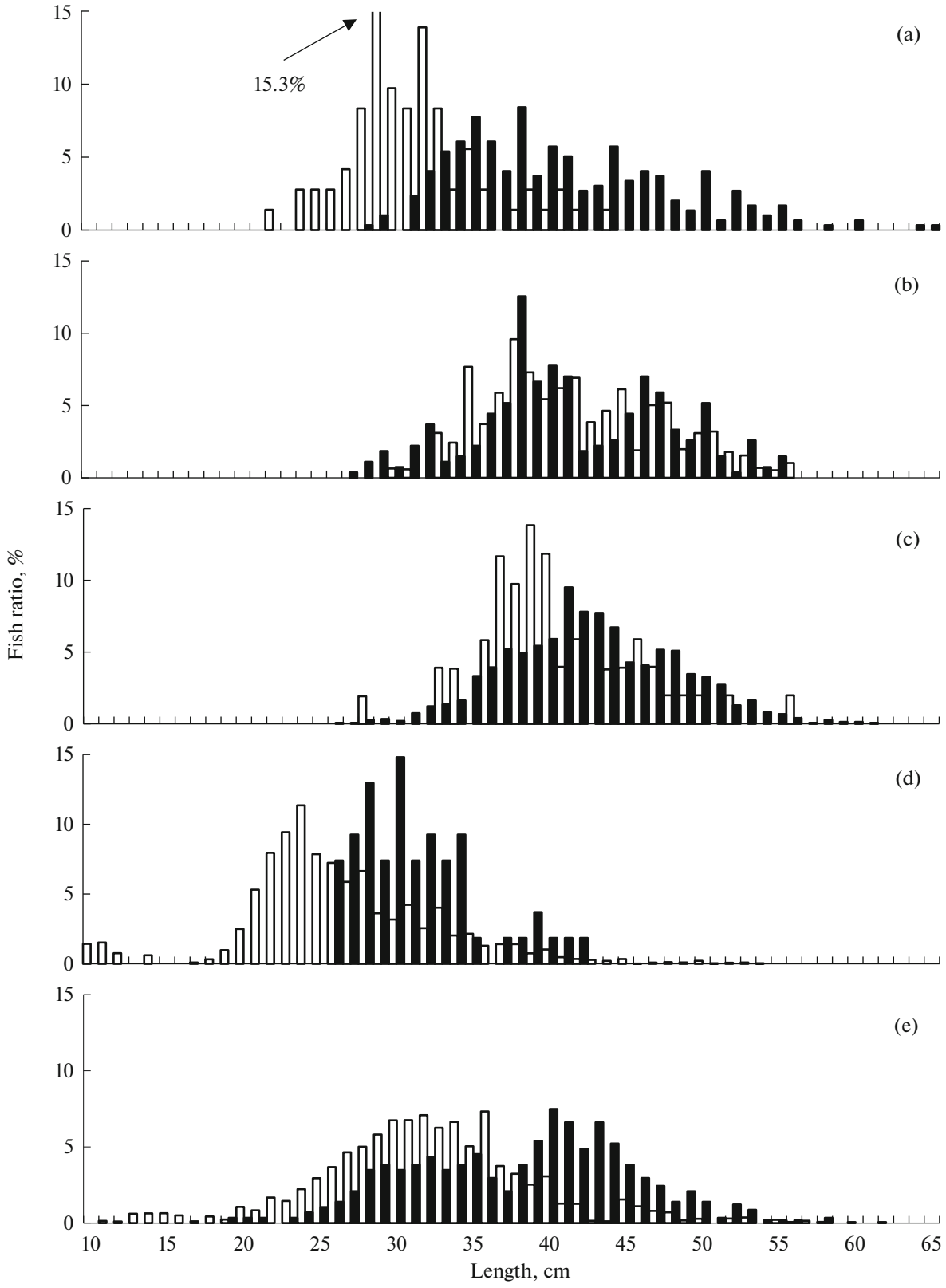

Fig. 10. Size structure (*FL*) of the Alaska plaice *Pleuronectes quadrituberculatus* in the catches of the bottom trawls and snurrevads in Olyutorsky-Navarin region of the Bering Sea in different years: (a) 1996 (trawl) and 1998 (snurrevad), (b) 1999, (c) 2000 (snurrevad) and 2001 (trawl), (d) 2004, (e) 2005; refer to Fig. 1 for the keys.

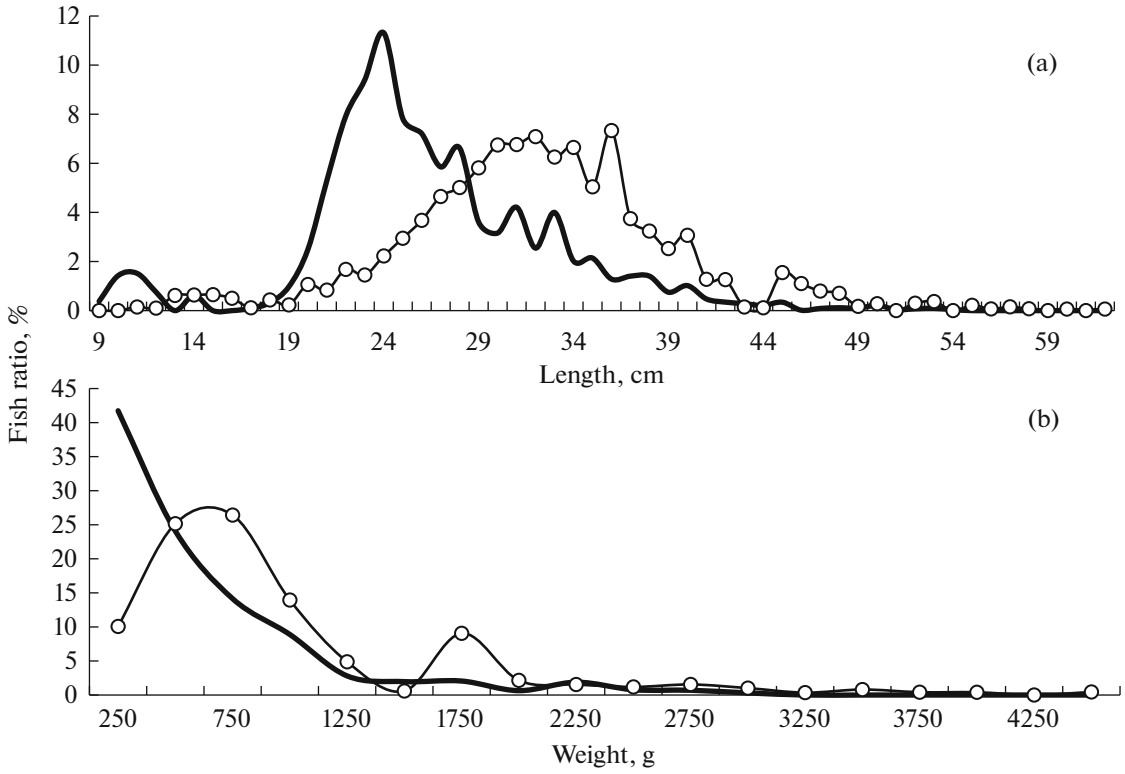

Fig. 11. Size structure (*FL*) and weight spectra of the Alaska plaice *Pleuronectes quadrituberculatus* in Olyutorsky-Navarin region according to the trawl catches 2004 and 2005: (a) body length (2004: $M = 26.5$ cm, $n = 960$ ind.; 2005: $M = 32.2$ cm, $n = 713$ ind.), (b) body weight (2004: $M = 366$ d, $n = 960$ ind.; 2005: $M = 655$ d, $n = 713$ ind.); refer to Fig. 3 for the keys.

coastal areas of the shelf in 2004–2005, where the juveniles of the northern rock sole preferred to stay (Datsky and Andronov, 2007). The 0.3–1.2-kg fish is the major group in the gatherings. Specimens *FL* 28–36 cm probably contribute to the increased ratio of the sole of 0.3–0.8 kg, and *FL* 38–45 cm, 0.9–1.4 kg (Fig. 15).

In general, larger specimens were caught by snurrevads: *FL* 21–55 cm, specimens *FL* 29–40 cm (more than 84%), mode 33–36 cm, dominated; the ratio of

Table 6. Gonad ratio of the Alaska plaice *Pleuronectes quadrituberculatus* in Olyutorsky-Navarin region of the Bering Sea in August–November, %

Month, year	Sex	Stage of gonad ripeness					Number of fish, ind.
		II	III	IV	V	VI–II	
Aug.–Sept. 1996	Females	50.0	12.5	37.5	0	0	16
	Males	25.0	62.5	12.5	0	0	8
Aug.–Sept. 1999	Females	30.1	30.1	2.4	0	37.3	83
	Males	94.7	1.3	4.0	0	0	75
Sept.–Oct. 2001	Females	26.2	28.6	42.9	2.4	0	42
	Males	11.7	85.0	3.3	0	0	60
Aug. 2002	Females	39.1	60.9	0	0	0	23
	Males	13.9	86.1	0	0	0	36
Oct.–Nov. 2004	Females	84.6	6.0	9.4	0	0	351
	Males	46.6	41.5	11.9	0	0	277
Aug.–Sept. 2005	Females	33.3	48.7	17.9	0	0	39
	Males	57.4	42.6	0	0	0	54

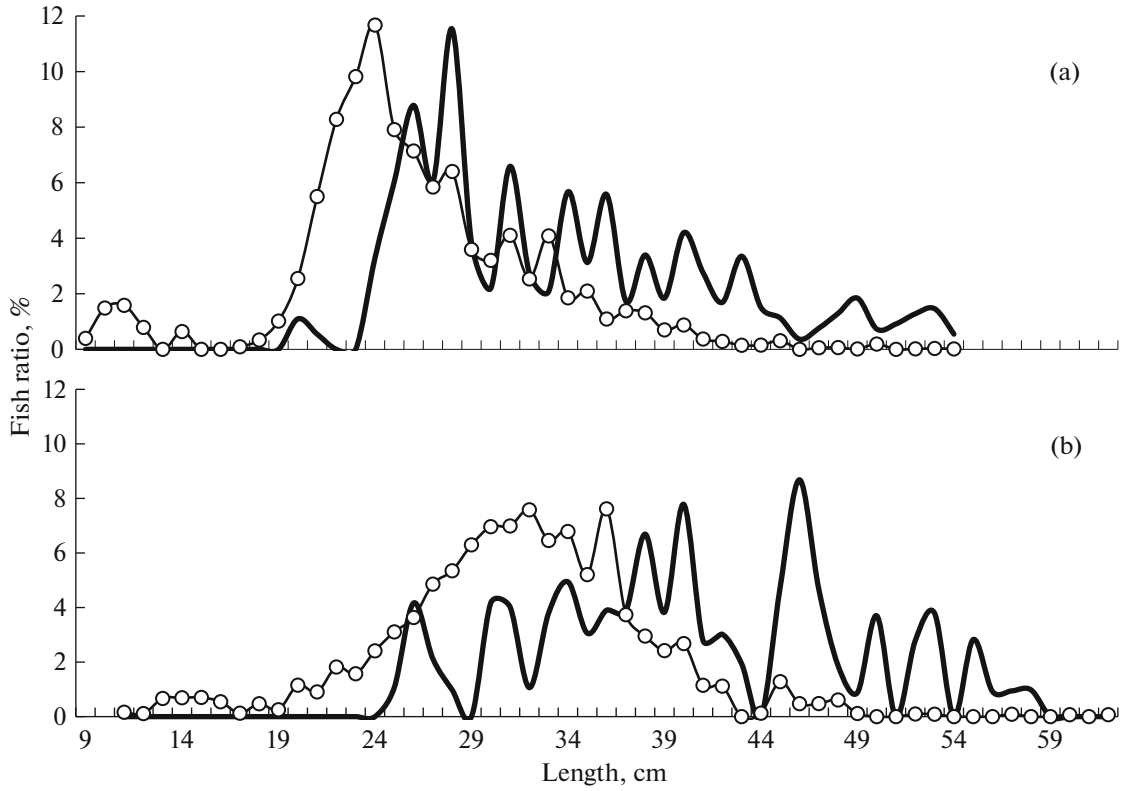

Fig. 12. Size structure (*FL*) of the Alaska plaice *Pleuronectes quadrituberculatus* in Exclusive Economic Zone and territorial waters of Olyutorsky-Navarin region according to the trawl catches: (a) 2004 (EEZ: $M = 33.6$ cm, $n = 50$ ind.; territorial waters: $M = 26.1$ cm, $n = 910$ ind.), (b) 2005 ($M = 40.4$ cm, $n = 54$ ind.; $M = 31.5$ cm, $n = 659$ ind., respectively); refer to Fig. 4 for the keys.

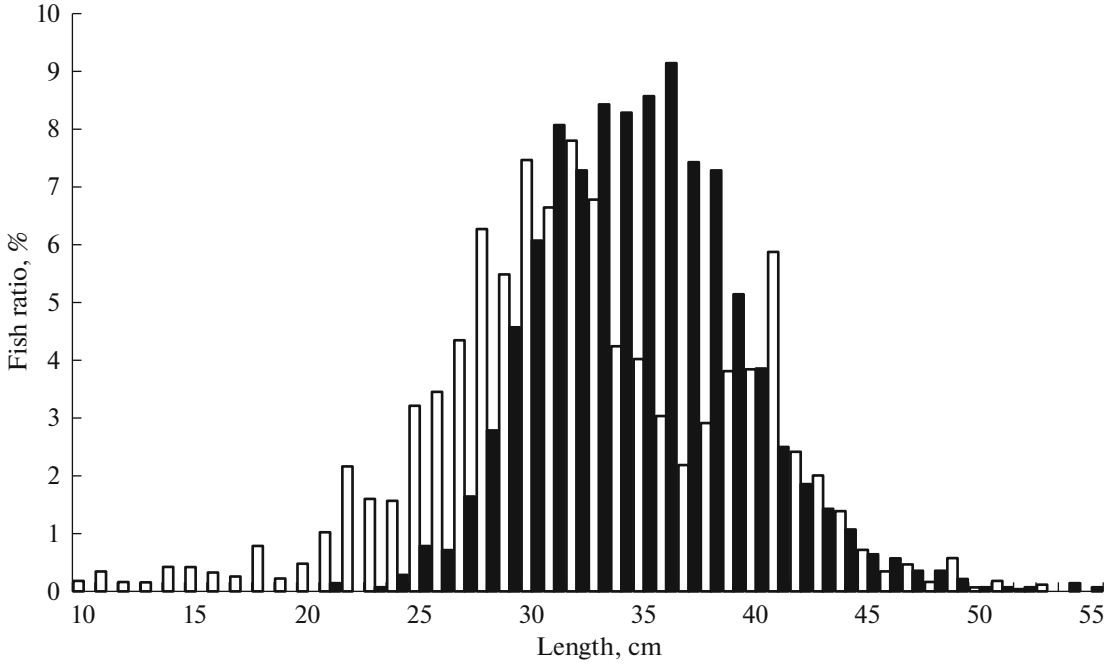

Fig. 13. Size structure (*FL*) of the northern rock sole *Lepidopsetta polyxystra* in Olyutorsky-Navarin region of the Bering Sea in 1995–2015 in the catches of the bottom trawls ($M = 32.3$ cm, $n = 1936$ ind.) and snurrevads ($M = 34.8$ cm, $n = 1400$ ind.); refer to Fig. 1 for the keys.

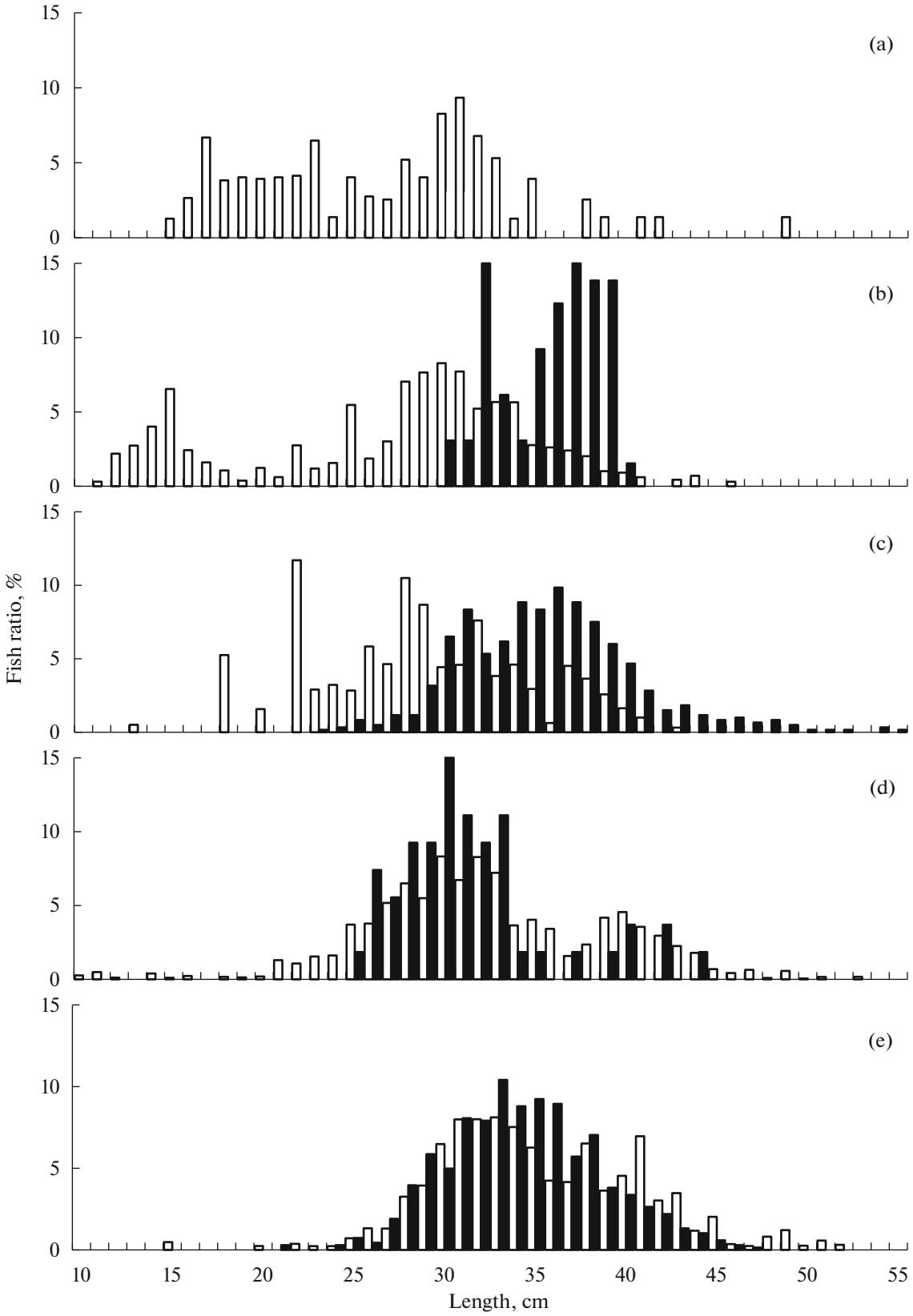

Fig. 14. Size structure (*FL*) of the northern rock sole *Lepidopsetta polyxystra* in the catches of the bottom trawls and snurrevads in Olyutorsky-Navarin region of the Bering Sea: (a) 1996, (b) 1999, (c) 2000 (snurrevad) and 2001 (trawl), (d) 2004, (e) 2005; refer to Fig. 1 for the keys.

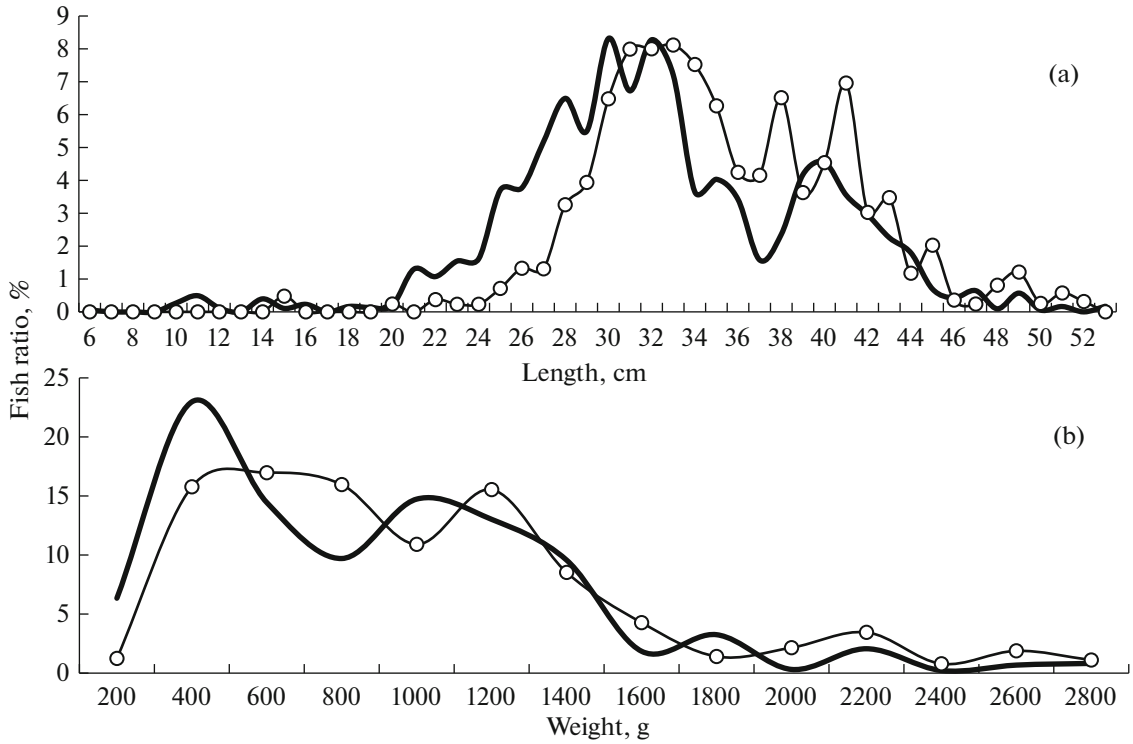

Fig. 15. Size structure (*FL*) and weight spectra of the northern rock sole *Lepidopsetta polyxystra* in Olyutorsky-Navarin region according to the trawl catches 2004 and 2005: (a) body length (2004: $M = 32.5$ cm, $n = 849$ ind.; 2005: $M = 35.3$ cm, $n = 344$ ind.), (b) body weight (2004: $M = 606$ d, $n = 849$ ind.; 2005: $M = 769$ d, $n = 344$ ind.); refer to Fig. 3 for the keys.

juveniles did not exceed 0.6% of the total catch by abundance (Table 7).

The juveniles of the northern rock sole $FL < 25$ cm of the age 4–8 years preferred the shallow areas of the Koryak shelf down to the depths of 40–60 m; they were nearly absent outside the coastal waters. The other size groups were found both within the territorial waters and deeper, probably, due to the narrow shelf of the study area. Regard must be paid to *FL* 25–34 cm of the age 9–13 years that preferred to keep mostly at the shallow waters compared to the larger fish (Fig. 16).

During the first three years of life, the northern rock sole reaches *FL* 16–17 cm; later, the linear growth rate slows down to 2.4–3.6 cm per year in 11-year old fish. The weight gain is relatively low during the first years, but it increases greatly after the fish reach the age 8 years, then it varies between 150–170 g per year, on average (Fadeev, 2005). Relatively low growth rate (in terms of body weight) is a particular feature of this species (Fadeev, 1971). According to our data, the total weight gain was 58 g per 1 cm: in the size groups of 21–30, 31–40, 41–50 cm, and ≥51 cm, the weight gain per 1 cm was 26, 62, 93, and 200 g, respectively. These rates are higher than those in the Alaska plaice, which is characterized by relatively high growth rates in terms of body weight. Therefore, we may state the favorable conditions of the growth of the northern rock sole in Olyutorsky-Navarin region during the study period.

In the northern rock sole, the dependence of body weight on the body length is described by the following equations: in the bottom trawls, $W = 0.0102\ FL^{3.0809}$ ($r = 0.97$, $n = 758$ ind.); in snurrevads, $W = 0.0039\ FL^{3.3326}$ ($r = 0.96$, $n = 150$ ind.).

The northern rock sole is characterized by well-pronounced sex dimorphism. The females are larger than males of the same age both in terms of body length and body weight. The difference by the body length in the trawl catches was, on average, 5.0 cm, 0.27 kg by the body weight, and 5.5 cm and 0.33 kg, respectively, in snurrevads (Table 7). The females' abundance exceeded that of males in by 1.5–2.0 times in the study area.

In the northwestern Bering Sea, the females of the northern rock sole mature en masse at *FL* 24–27 cm and the age 6–7 years; males mature 1–2 years earlier at *FL* 21–25 cm, as is observed for the other species of the righteye flounders inhabiting the Far East region (Fadeev, 1987; V.V. Bazuev and S.A. Pal'm, personal communication).

The spawning period of the northern rock sole starts in winter and ends in June (Pertseva-Ostroumova, 1961). According to our data, the spawning and recently spawned specimens are also found in August,

Table 7. Body length, body weight, and the sex ratio of the northern rock sole *Lepidopsetta polyxystra* in the catches in Olyutorsky-Navarin region of the Bering Sea

Study period (month, year)	Number of fish, ind.	Length (*FL*), cm			Weight, kg			Females : males ratio
		females	males	both sexes	females	males	both sexes	
Bottom trawl, mesh size in the cod end 10–12 mm								
Sept. 1996	71	33.8	30.6	32.2	0.623	0.408	0.511	0.9 : 1.0
Aug.–Sept. 1999	91	32.8	29.5	31.7	0.481	0.306	0.417	1.7 : 1.0
Sept.–Oct. 2001	407	32.8	25.7	30.1	0.610	0.282	0.487	1.7 : 1.0
Aug. 2002	141	35.8	29.4	34.2	0.698	0.354	0.615	3.1 : 1.0
Aug.–Sept. 2003	50	31.5	28.4	30.2	0.448	0.294	0.386	1.5 : 1.0
Oct.–Nov. 2004	607	34.8	28.7	33.1	0.747	0.342	0.625	1.0 : 1.0
Aug.–Sept. 2005	103	36.8	31.2	34.0	–	–	0.602	0.8 : 1.0
July–Aug. 2008	1165	36.0	29.4	30.3	–	–	0.586	2.2 : 1.0
July–Aug. 2012	371	–	–	30.3	–	–	0.403	2.5 : 1.0
Bottom trawl, mesh size in the cod end 60 mm								
Oct. 2008	668	39.7	33.5	37.2	0.875	0.493	0.801	4.2 : 1.0
Snurrevad, mesh size 35–40 mm								
Aug.–Sept. 1998	100	40.0	30.6	36.9	0.883	0.352	0.708	2.0 : 1.0
July–Aug. 2000	50	39.5	36.3	39.3	0.928	0.657	0.912	15.7 : 1.0
Aug.–Sept. 2005	100	33.7	29.8	32.5	0.496	0.319	0.440	2.1 : 1.0

Table 8. Gonad ratio of the northern rock sole *Lepidopsetta polyxystra* in Olyutorsky-Navarin region of the Bering Sea in August–November, %

Month, year	Sex	Stage of gonad ripeness					Number of fish, ind.
		II	III	IV	V	VI–II	
Aug.–Sept. 1996	Females	54.8	0	45.2	0	0	31
	Males	11.4	82.9	5.7	0	0	35
Aug.–Sept. 1999	Females	38.9	40.0	21.1	0	0	90
	Males	55.0	5.0	12.5	10.0	17.5	40
Sept.–Oct. 2001	Females	39.0	44.6	0	16.4	0	269
	Males	50.3	49.7	0	0	0	153
Aug. 2002	Females	64.5	33.6	0	0	1.9	107
	Males	88.2	11.8	0	0	0	34
Oct.–Nov. 2004	Females	40.9	33.6	25.6	0	0	301
	Males	21.9	69.0	9.2	0	0	306
Aug.–Sept. 2005	Females	63.0	37.0	0	0	0	46
	Males	66.7	33.3	0	0	0	57
Oct. 2008	Females	39.9	60.1	0	0	0	500
	Males	15.6	84.4	0	0	0	168

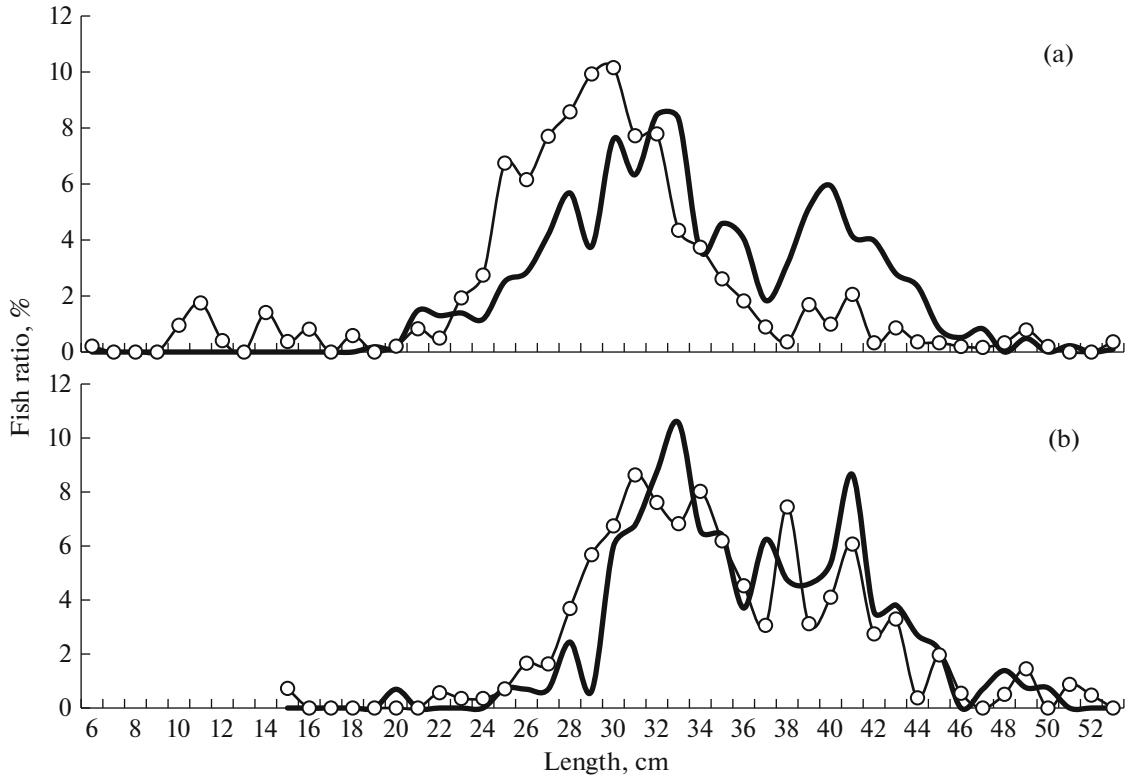

Fig. 16. Size structure (*FL*) of the northern rock sole *Lepidopsetta polyxystra* in Exclusive Economic Zone and territorial waters of Olyutorsky-Navarin region according to the trawl catches: (a) 2004 (EEZ: $M = 33.7$ cm, $n = 610$ ind.; territorial waters: $M = 29.3$ cm, $n = 239$ ind.), (b) 2005 ($M = 36.2$ cm, $n = 118$ ind.; $M = 34.9$ cm, $n = 226$ ind., respectively); refer to Fig. 4 for the keys.

mostly in the cold years: in August–November 1999 and 2002, most of the specimens carried the gonads of stage II and III (Table 8). The data on the egg distribution in this study area are absent; there are only data on the larvae of this species (up to 6 ind./m^2) along the Koryak coast and in the southwestern Gulf of Anadyr within the 100-m isobathic line (Pertseva-Ostroumova, 1961).

The flat-headed flounders of genus *Hippoglossoides* (flathead sole *H. elassodon* and the Bering flounder

Table 9. Body length, body weight, and the sex ratio of the flat-headed flounders *Hippoglossoides elassodon* and *H. robustus* in the catches in Olyutorsky-Navarin region of the Bering Sea

Study period (month, year)	Number of fish, ind.	Length (*FL*), cm			Weight, kg			Females : males ratio
		females	males	both sexes	females	males	both sexes	
Bottom trawl, mesh size in the cod end 10–12 mm								
Sept. 1996	58	33.6	30.9	32.5	0.384	0.276	0.339	1.4 : 1.0
Aug.–Sept. 1999	64	30.7	30.2	30.6	0.344	0.284	0.327	2.5 : 1.0
Sept.–Oct. 2001	276	27.8	22.8	25.6	0.286	0.163	0.231	1.2 : 1.0
Aug. 2002	190	26.1	22.8	26.0	0.249	0.117	0.205	2.0 : 1.0
Oct.–Nov. 2004	242	–	–	28.7	–	–	0.277	2.1 : 1.0
Aug.–Sept. 2005	42	27.8	23.1	25.8	–	–	0.241	1.3 : 1.0
July–Aug. 2012	60	–	–	26.0	–	–	0.115	3.7 : 1.0
Snurrevad, mesh size 35–40 mm								
Aug.–Sept. 1998	57	32.4	26.5	31.5	0.366	0.207	0.344	6.1 : 1.0
July–Sept. 1999	70	–	–	33.1	–	–	–	–
July–Aug. 2000	161	–	–	34.5	–	–	–	–

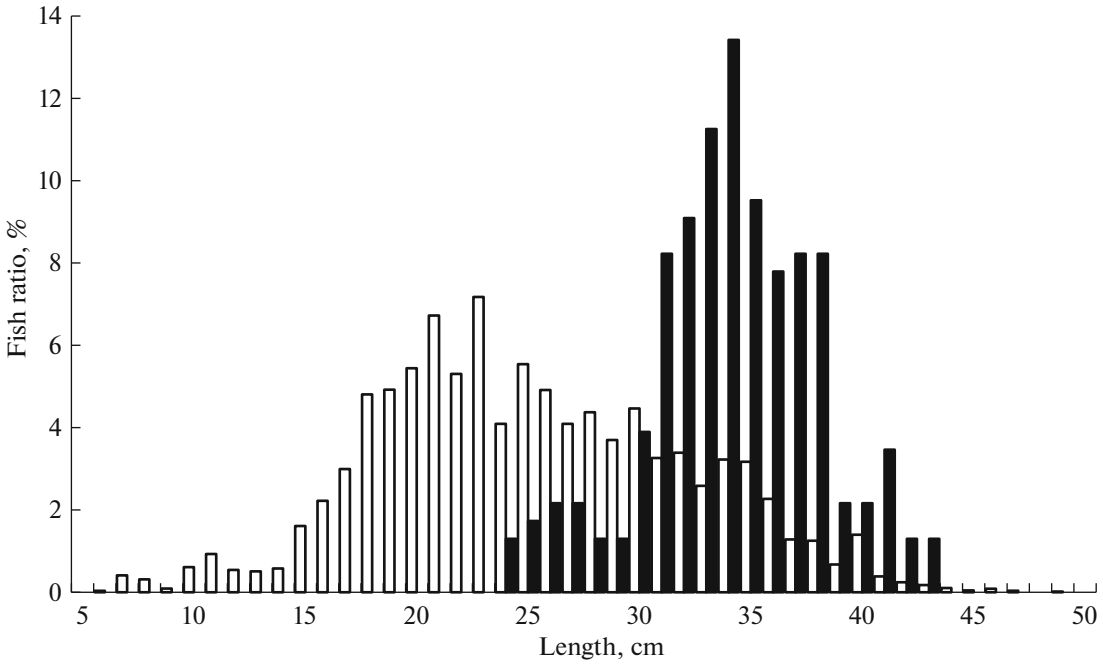

Fig. 17. Size structure (*FL*) of the flat-headed flounders *Hippoglossoides elassodon* and *H. robustus* in Olyutorsky-Navarin region of the Bering Sea in 1995–2015 in the catches of the bottom trawls (M = 25.3 cm, n = 2755 ind.) and snurrevads (M = 34.1 cm, n = 231 ind.); refer to Fig. 1 for the keys.

H. robustus) in the Bering Sea reach *FL* 58 cm, body weight 1.8 kg, and 27 years; the specimens *FL* 27–40 cm and body weight 0.23–0.88 kg dominate in the catches (Fadeev, 1987; Munk, 2001). In the northwestern Bering Sea, these flounders are smaller and more elongated compared to the northern rock sole and the Alaska plaice. In trawl-like gear, the specimens *FL* 1–50 cm form the catch with the dominating group of mature specimens *FL* 24–36 cm; the maximal age is 22 years (Datsky and Andronov, 2007).

The Olyutorsky-Navarin region is inhabited mostly by the flathead sole, and the Bering flounder is more abundant in the Gulf of Anadyr. The specimens *FL* 6–49 cm and body weight 0.006–1.180 kg of both species[1] are registered in trawl catches; the dominant group were the fish *FL* 18–30 cm (more than 65%), mode 21–23 cm (Fig. 17). Larger specimens *FL* 24–43 cm are caught by snurrevads with dominating group *FL* 30–38 cm (approximately 80%), mode 32–35 cm. The immature fish *FL* < 18 cm were totally absent in this type of the fishing gear, although their ratio in the trawl reached up to 11% (Table 9).

As was observed for the northern rock sole, the relative abundance of the juveniles of the flat-headed flounders *FL* < 20 cm decreased also: in 1999, 2001, and 2002, their ratio in trawl catches varied between 17.1–41.5% (Figs. 18a–18c); however, it did not exceed 5.8% in 2004–2005 (Figs. 18d and 18e). Generally, during the last years, the specimens *FL* 23–36 cm dominated, and the most of the catch were the fish of 0.2–0.5 kg (Fig. 19).

In the northwestern Bering Sea, the juveniles of the flat-headed flounders prefer the depths of less than 40 m, while the largest specimens prefer the shelf areas with the depths of 100 m and more, i.e., the size of the fish increases in accordance with the depth (Datsky and Andronov, 2007). In Olyutorsky-Navarin region, such distributional pattern is not usual. Due to the narrow Koryak shelf, immature and adult fish form the mixed gatherings both in the coastal areas and at the areas of greater depths (Fig. 20).

The flat-headed flounders are considered to be relatively large-size fish among the other species of flounders, soles, and plaices; however, the weight gain in regard to the linear growth is lower compared to the other species. In the middle-size specimens, the weight gain is 50 g per each 2 cm of the body length increase, in large flounders, 90 g (Fadeev, 1971). According to our data, the total weight gain per 1 cm is significantly lower: 16, 43, and 57 g in the size groups 21–30, 31–40, and 41–50 cm, respectively, or 28 g on average. These parameters are lower compared to the Alaska plaice (51 g) and the northern rock sole (58 g).

In the flat-headed flounders, the dependence of body weight on the body length is described by the following equations: in the bottom trawls, W = 0.0059

[1] In particular surveys, these two species were pooled together as the group of the flat-headed flounders, so here we also present the pooled data.

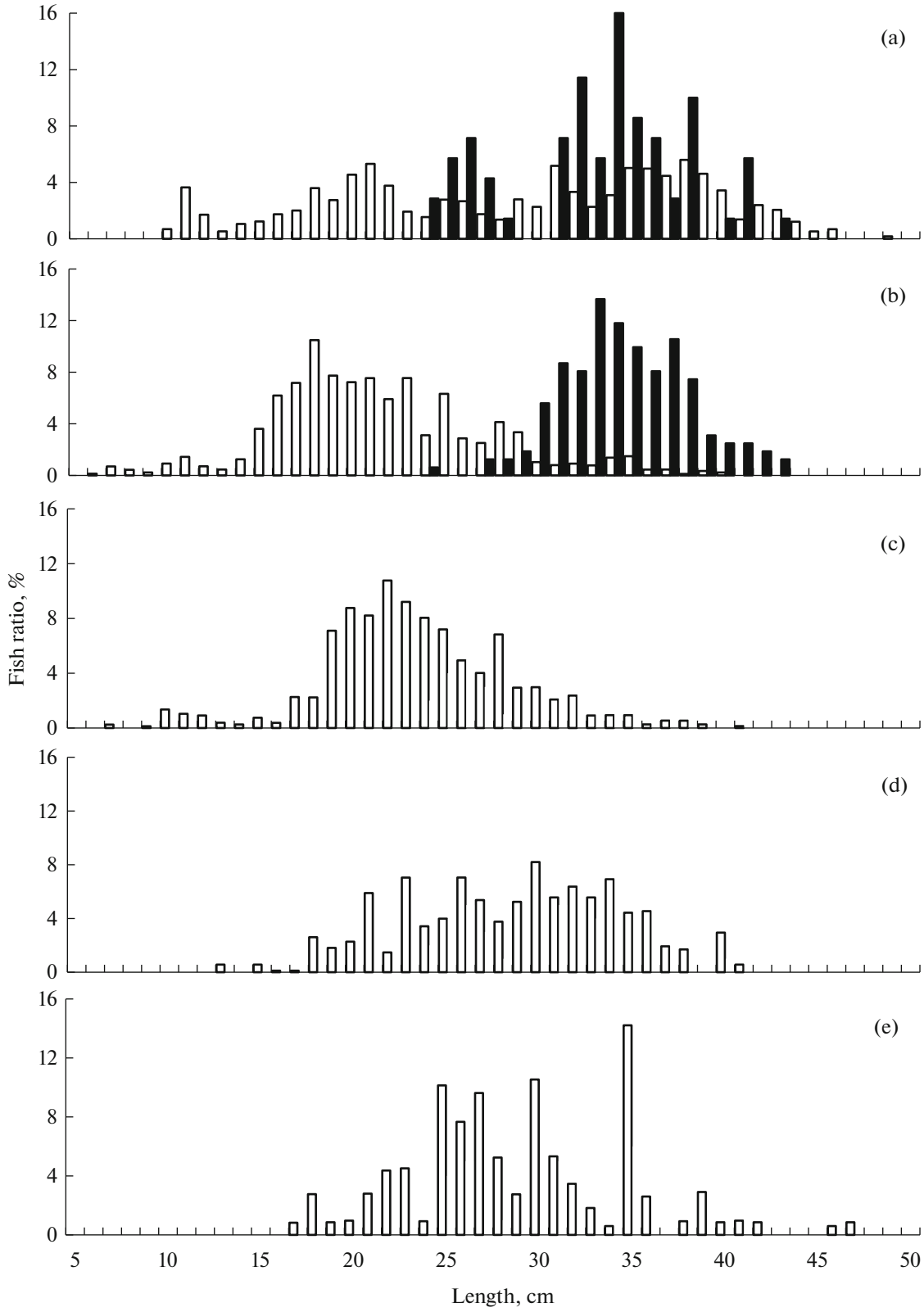

Fig. 18. Size structure (*FL*) of the flat-headed flounders *Hippoglossoides elassodon* and *H. robustus* in the catches of the bottom trawls and snurrevads in Olyutorsky-Navarin region of the Bering Sea in different years: (a) 1999, (b) 2000 (snurrevad) and 2001 (trawl), (c) 2002, (d) 2004, (e) 2005; refer to Fig. 1 for the keys.

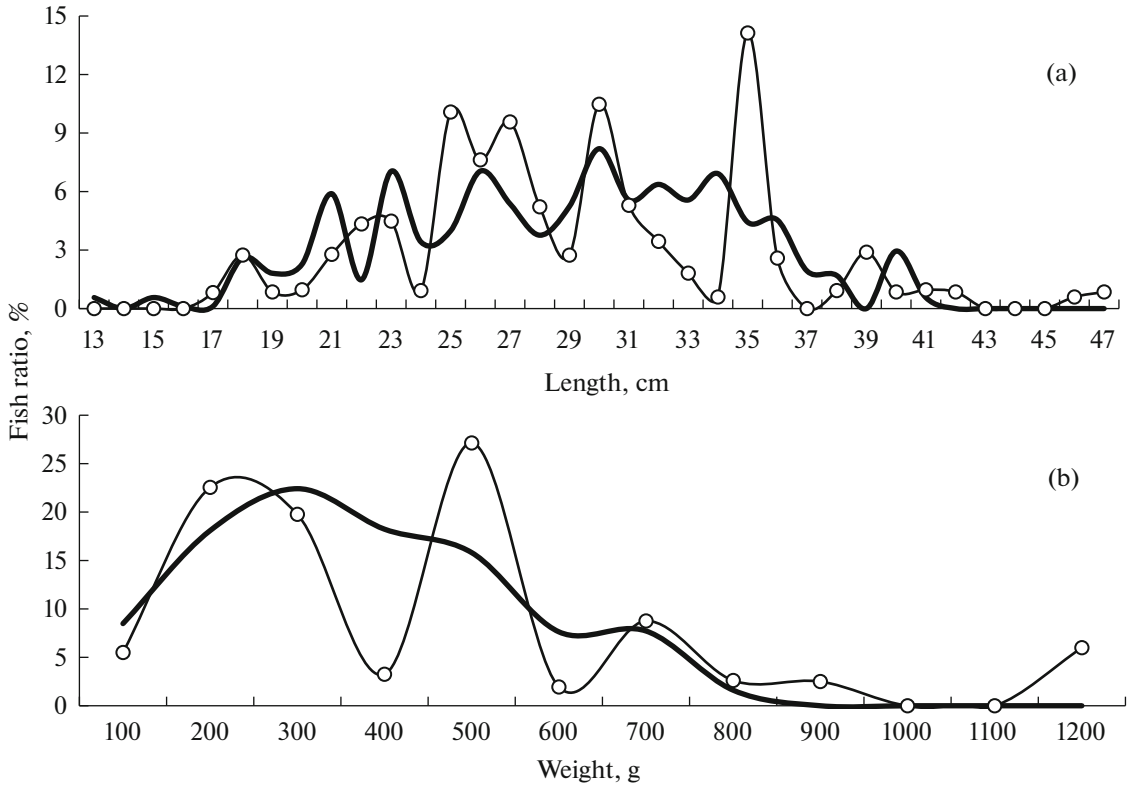

Fig. 19. Size structure (*FL*) and weight spectra of the flat-headed flounders *Hippoglossoides elassodon* and *H. robustus* in Olyutorsky-Navarin region according to the trawl catches 2004 and 2005: (a) body length (2004: $M = 28.7$ cm, $n = 242$ ind.; 2005: $M = 28.9$ cm, $n = 93$ ind.), (b) body weight (2004: $M = 277$ g, $n = 242$ ind.; 2005: $M = 291$ g, $n = 93$ ind.); refer to Fig. 3 for the keys.

$FL^{3.1558}$ ($r = 0.98$, $n = 619$ ind.); in snurrevads, $W = 0.0102\ FL^{2.9913}$ ($r = 0.98$, $n = 57$ ind.).

The flat-headed flounders are characterized by well-pronounced sex dimorphism. The females in the population are larger and older than males (Borets, 1997). According to our data, the difference between the females and males in the body length and weight was, on average, 3.5 cm and 0.12 kg; the females' abundance exceeded that of males (Table 9).

Before they mature, the linear growth of the flat-headed flounders varies between 5–8 cm per year, then the growth rate slows down, and it varies between 2.5–3.2 cm per year after they reach 4 years. The annual growth in 7–10-year old females is 2.6 cm (V.V. Bazuev and S.A. Pal'm, personal communica-

Table 10. Gonad ratio of the flat-headed flounders *Hippoglossoides elassodon* and *H. robustus* in Olyutorsky-Navarin region of the Bering Sea in August–November, %

Month, year	Sex	Stage of gonad ripeness					Number of fish, ind.
		II	III	IV	V	VI–II	
Aug.–Sept. 1996	Females	87.5	9.4	3.1	0	0	32
	Males	66.7	0	22.2	11.1	0	9
Aug.–Sept. 1999	Females	80.4	19.6	0	0	0	46
	Males	61.1	0	5.6	0	33.3	18
Sept.–Oct. 2001	Females	56.3	32.5	11.3	0	0	151
	Males	31.5	61.3	6.5	0.8	0	124
Aug. 2002	Females	87.4	11.8	0	0	0.8	127
	Males	69.8	25.4	0	0	4.8	63
Oct.–Nov. 2004	Females	54.8	23.0	22.2	0	0	135
	Males	34.4	53.1	12.5	0	0	64

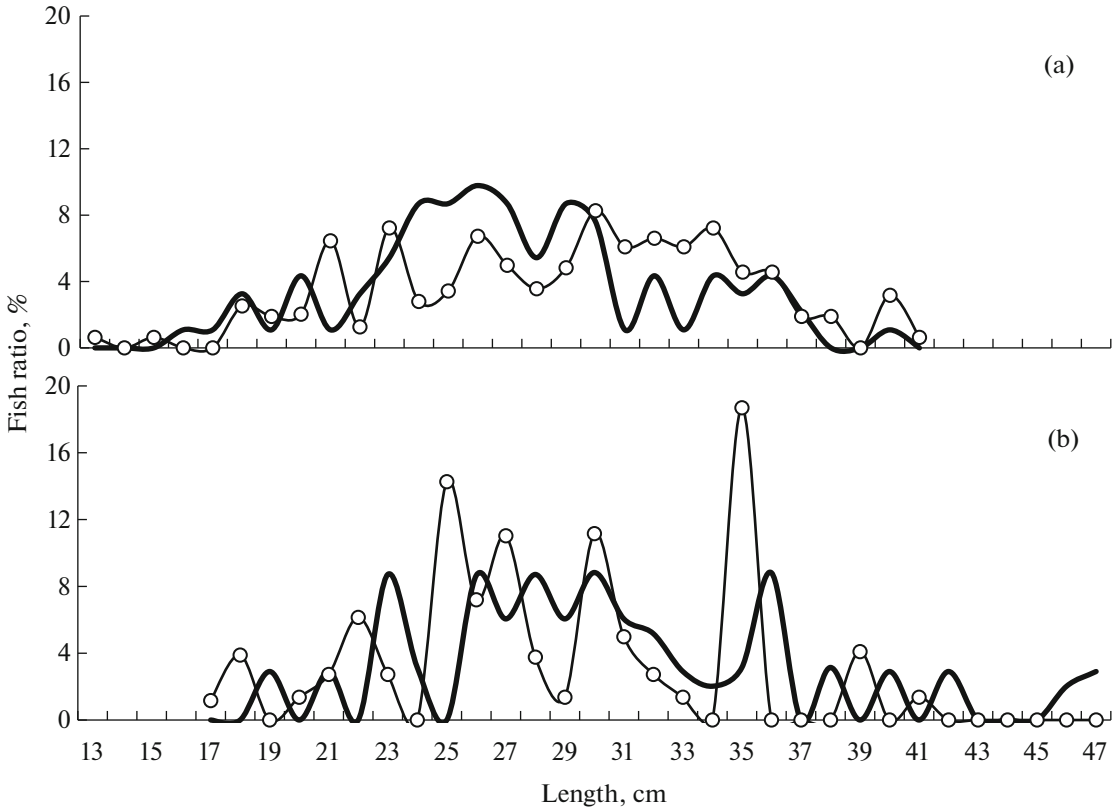

Fig. 20. Size structure (*FL*) of the flat-headed flounders *Hippoglossoides elassodon* and *H. robustus* in Exclusive Economic Zone and territorial waters of Olyutorsky-Navarin region according to the trawl catches: (a) 2004 (EEZ: $M = 27.2$ cm, $n = 30$ ind.; territorial waters: $M = 28.9$ cm, $n = 212$ ind.), (b) 2005 ($M = 30$ cm, $n = 27$ ind.; $M = 28.5$ cm, $n = 66$ ind., respectively); refer to Fig. 4 for the keys.

tion); this is lower compared to the females of the Alaska plaice and the northern rock sole of the same age (3.5 and 3.4 cm, respectively). The low growth rates of the flat-headed flounders are probably preconditioned by the food competition and the food supply in general.

In the eastern Bering Sea, the males of the flat-headed flounders mature en masse (50% of the generation abundance) at the age 6–9 years (*FL* 18–37 cm), females, at 7–8 years (18–39 cm) (Fadeev, 1987). In the northwestern Bering Sea, the females mature at the age 7–9 years and *FL* 21–24 cm (V.V. Bazuev and S.A. Pal'm, personal communication).

The flat-headed flounders spawn in spring. In the northwestern Bering Sea, their spawning en masse occurs in early hydrological spring (from mid-April through mid-June) at the depths of 20–140 m and the water temperature of the near-bottom layer of –1.72–2.36°C (Pertseva-Ostroumova, 1961; Fadeev, 1987; Borets, 1997). Their spawning period may last up to August, especially in the cold years; however, most of the fish are characterized by the resting gonads or the gonads that have just started to mature (Table 10).

The highest densities of the eggs of the flathead sole (up to 34 egg/m^2) were registered southeast off Navarin Cape at the areas of 100-m depth, those of the Bering flounder (up to 71 egg/m^2) were registered in the southwestern Gulf of Anadyr, abeam Ugol'naya Bay, above the depths of 65 m (Pertseva-Ostroumova, 1961). Unfortunately, due to the absence of the targeted studies, the areas preferred by the larvae and juveniles of these species still remain unknown.

Yellowfin sole *Limanda aspera* reaches the largest size of 49 cm and weight 1.7 kg. The specimens *FL* 20–35 cm and body weight 0.15–0.50 kg are the dominant group in the catches (Fadeev, 1971, 1987, 2005). In the northwestern Bering Sea, the high abundance of this species was registered only along the Koryak shelf; the yellowfin sole catches are low when harvesting by the trawl and snurrevads in the southern Bering Sea.

In the trawl catches performed in Olyutorsky-Navarin region, the yellowfin sole *FL* 12–44 cm was present by the dominant groups of *FL* 17–21 (52.4%) and 28–32 cm (13.9%) (Fig. 21). The catch of the specimens *FL* 45 cm and body weight 1.42 kg of the age 19 years was also registered in this area. In the study period, the high ratio of the immature specimens *FL* < 19 cm (approximately 33%) was a usual feature of the trawl catches (Fig. 22). However, the ratio of this group was high (42.3%) only in August–September

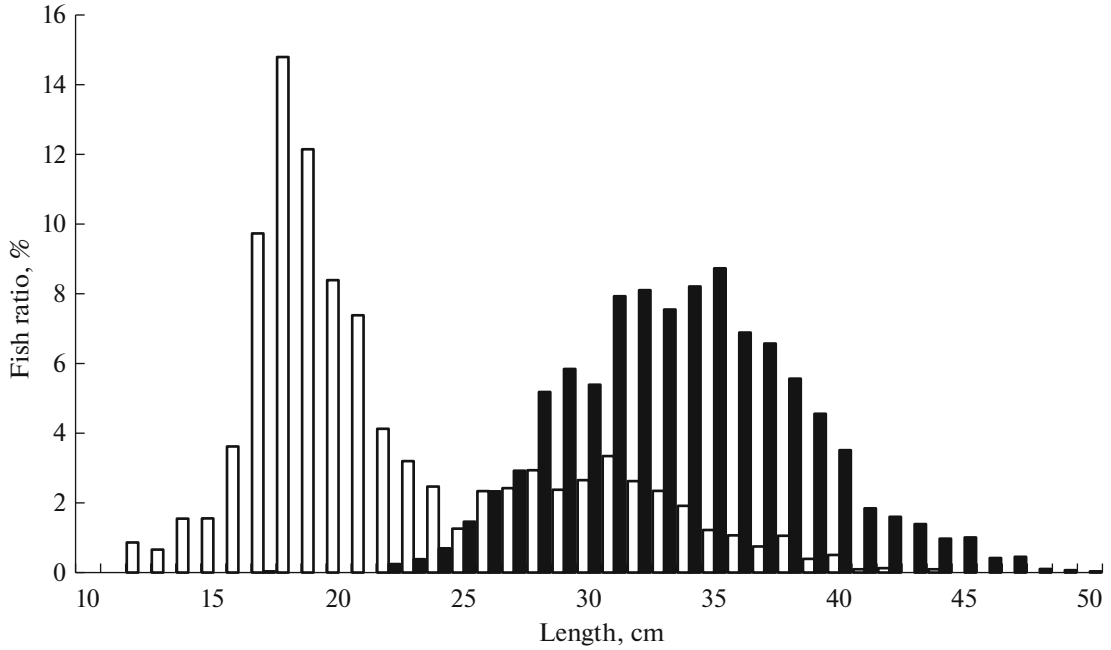

Fig. 21. Size structure (*FL*) of the yellowfin sole *Limanda aspera* in Olyutorsky-Navarin region of the Bering Sea in 1995–2015 in the catches of the bottom trawls ($M = 22.5$ cm, $n = 930$ ind.) and snurrevads ($M = 33.9$ cm, $n = 2875$ ind.); refer to Fig. 1 for the keys.

2005 (Fig. 22e); in the other years, the juveniles were either totally absent in the catches or their abundance was very low (Figs. 22a–22d). Body weight of the fish in trawl catches varied in different years: when the juveniles were abundant, the dominant group were the specimens 0.1–0.2 kg, while when they were absent, the dominant group were the specimens 0.35–0.50 kg (Fig. 23).

Opposite to the trawl catches, larger fish *FL* 22–50 cm were caught by snurrevads, the specimens *FL* 28–39 cm (80.5%), mode 31–35 cm, dominated (Fig. 21); the body weight varied between 0.18–1.40 kg, 0.4–0.6 kg in the dominant group; the fish age was 7–19 years, and the dominant group were the 8–12-year old specimens.

Comparing the size-age parameters of the yellowfin sole in the Olyutorsky-Navarin region and from the other habitats (Moiseev, 1953; Fadeev, 1971; Borets, 1997), we conclude that the population of the study area is stable, and it is presented by the older specimens. The decrease of the average size of the fish in 2005 was probably not the result of the increase of the ratio of the young specimens due to the intensive harvesting but due to the high crop yield of the particular generations. Particularly, there was a tendency of decrease of the ratio of the large specimens in both trawls and snurrevads from 1998 through 2005. In 1999, the majority of the catch were the fish of the size group 29–36 cm, but 29–34 cm in 2001, and 27–33 cm in 2004 (Figs. 22b–22d); in snurrevad catches in 1998, specimens *FL* 32–40 cm dominated, while those 30–37, 28–37, and 28–36 cm, respectively, dominated in 1999, 2000, and 2005 (Figs. 22a–22c and 22e).

In the warm period, the fish of different size tend to separate the habitats, when the body size and the age increases in accordance to the depth. The yearlings and 2-year old juveniles prefer the coastal zone, the mature specimens usually inhabit the depths of more than 20 m (Fadeev, 2005). There was no such tendency found in the study area, when juveniles and adults formed the mixed gatherings (Fig. 24); this, probably, was linked to the narrow Koryak shelf, especially its southern part. The outer margin of this shelf keeps at 100–170-m depth; its width shrinks to 10 miles at 171° E (Udintsev et al., 1959).

It has been argued that the weight gain of the yellowfin sole was lower than in the Alaska plaice but higher than in the northern rock sole. The increase of the body length by 2 cm in the specimens of the yellowfin sole *FL* 30–32 cm leads to the weight gain of 65 g, and by 120 g in large fish *FL* 38–40 cm (Fadeev, 1971). According to our data, the average weight gain is 67 g per 1 cm: it is 20, 29, 56 and 136 g, respectively, in the size groups of 10–20, 21–30, 31–40, and 41–50 cm. These values are the highest when compared to the other abundant flounder species inhabiting the Olyutorsky-Navarin region.

In the yellowfin sole, the dependence of body weight on the body length is described by the following equations: in the bottom trawls, $W = 0.0117\ FL^{3.0434}$ ($r = 0.98$, $n = 340$ ind.); in snurrevads, $W = 0.0041\ FL^{3.3329}$ ($r = 0.96$, $n = 150$ ind.).

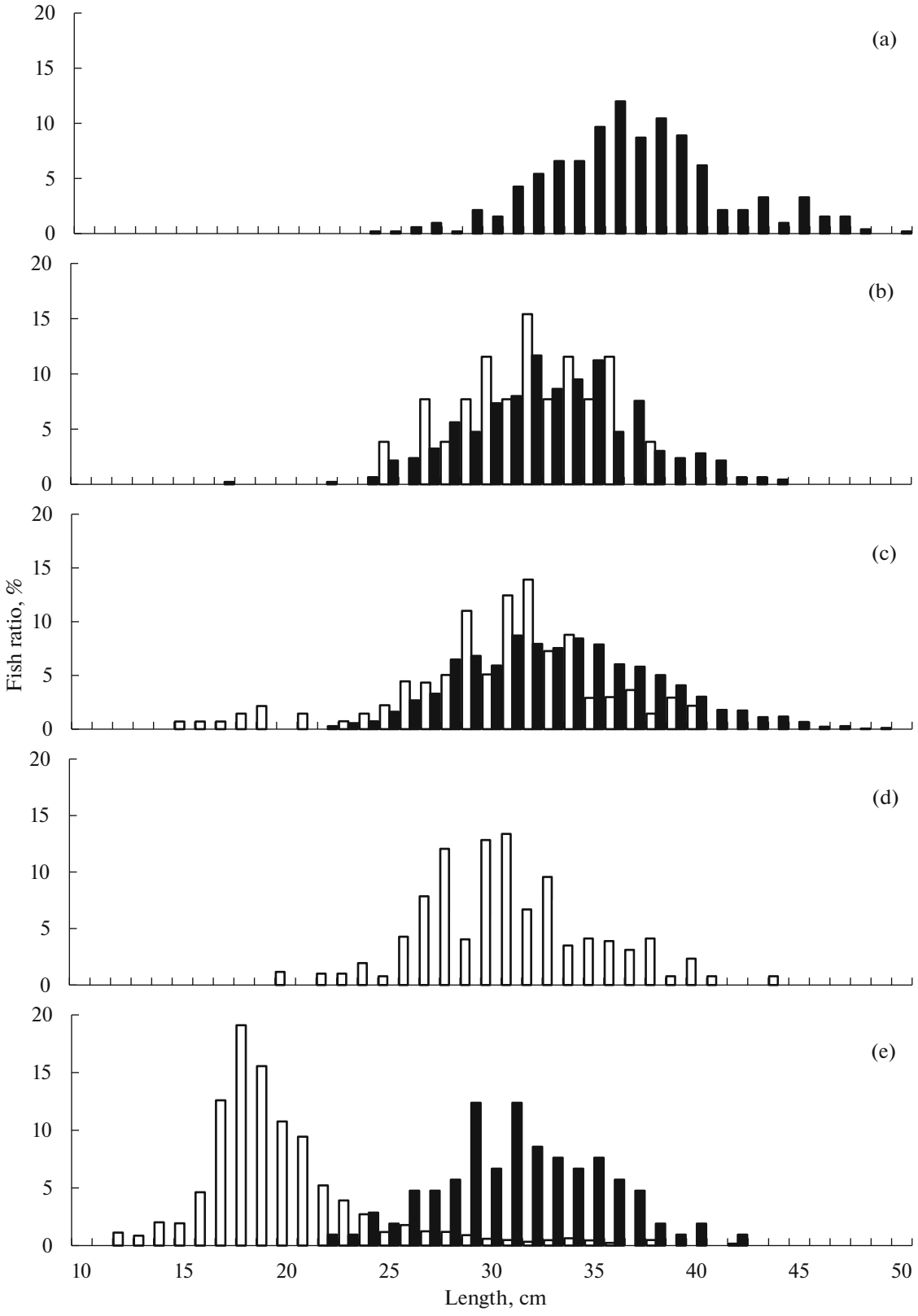

Fig. 22. Size structure (*FL*) of the yellowfin sole *Limanda aspera* in the catches of the bottom trawls and snurrevads in Olyutorsky-Navarin region of the Bering Sea in different years: (a) 1998, (b) 1999, (c) 2000 (snurrevad) and 2001 (trawl), (d) 2004, (e) 2005; refer to Fig. 1 for the keys.

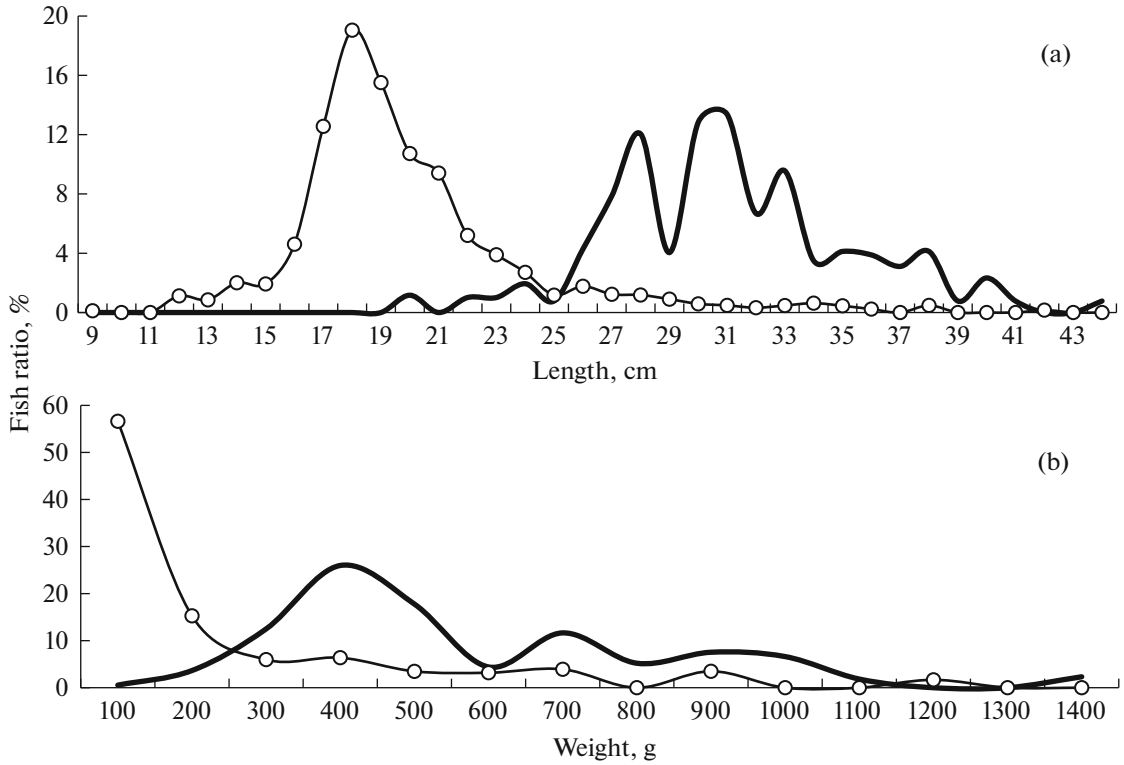

Fig. 23. Size structure (*FL*) and weight spectra of the yellowfin sole *Limanda aspera* in Olyutorsky-Navarin region according to the trawl catches 2004 and 2005: (a) body length (2004: $M = 31.1$ cm, $n = 83$ ind.; 2005: $M = 19.9$ cm, $n = 578$ ind.), (b) body weight (2004: $M = 479$ g, $n = 83$ ind.; 2005: $M = 120$ g, $n = 578$ ind.); refer to Fig. 3 for the keys.

Table 11. Body length, body weight, and the sex ratio of the yellowfin sole *Limanda aspera* in the catches in Olyutorsky-Navarin region of the Bering Sea

Study period (month, year)	Number of fish, ind.	Length (*FL*), cm			Weight, kg			Females : males ratio
		females	males	both sexes	females	males	both sexes	
	Bottom trawl, mesh size in the cod end 10–12 mm							
Sept. 1996	13	30.0	30.6	30.4	0.385	0.366	0.372	0.3 : 1.0
Sept.–Oct. 2001	13	21.9	21.6	21.7	0.176	0.165	0.170	0.9 : 1.0
Aug. 2002	65	32.8	27.2	31.8	0.516	0.270	0.474	4.9 : 1.0
Aug.–Sept. 2003	50	35.6	32.1	33.9	0.637	0.405	0.525	1.1 : 1.0
Oct.–Nov. 2004	64	32.7	28.9	31.1	0.617	0.268	0.479	1.1 : 1.0
Aug.–Sept. 2005	99	22.8	21.3	22.3	–	–	0.148	1.4 : 1.0
July–Aug. 2008	64	33.7	26.9	32.5	–	–	0.444	1.3 : 1.0
July–Aug. 2012	97	–	–	29.5	–	–	0.381	0.9 : 1.0
	Snurrevad, mesh size 35–40 mm							
Aug.–Sept. 1998	517	–	–	36.7	–	–	–	-
July–Sept. 1999	463	–	–	33.0	–	–	–	-
July–Aug. 2000	150	35.1	31.8	33.9	0.633	0.397	0.548	1.8 : 1.0
Aug.–Sept. 2005	105	–	–	31.4	–	–	–	-

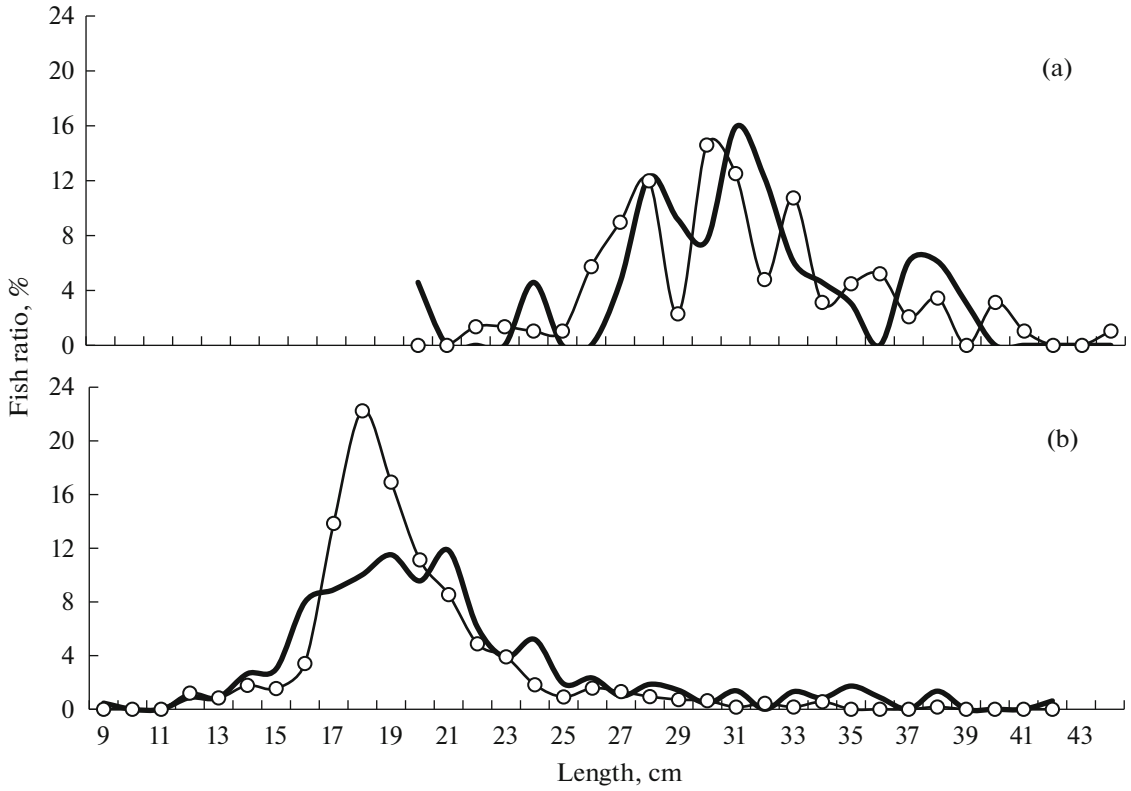

Fig. 24. Size structure (*FL*) of the yellowfin sole *Limanda aspera* in Exclusive Economic Zone and territorial waters of Olyutorsky-Navarin region according to the trawl catches: (a) 2004 (EEZ: $M = 30.9$ cm, $n = 25$ ind.; territorial waters: $m = 31.1$ cm, $n = 58$ ind.), (b) 2005 ($M = 21.1$ cm, $n = 151$ ind.; $M = 19.5$ cm, $n = 427$ ind., respectively); refer to Fig. 4 for the keys.

The females of the yellowfin sole are larger than males of the same age. In the study area, the differences between the average body length and body weight of females and males of the age 7–9 years are 3.0 cm and 0.22 kg (Table 11). This difference increases in regard to the age. The females' abundance in the catches is higher than that of males.

The yellowfin sole grows up relatively quickly during the first 2 years of life: it reaches *FL* 9–16 cm depending on the area of inhabitance. Later, the growth rate decreases down to 3–6 cm per year when reaching the age 5 years and down to 1.5–2.0 cm per year in the fish of older ages. The males mature for the first time at *FL* 12–25 cm in the Bering Sea, en masse,

Table 12. Gonad ratio of the yellowfin sole *Limanda aspera* in Olyutorsky-Navarin region of the Bering Sea in July–November, %

Month, year	Sex	Stage of gonad ripeness					Number of fish, ind.
		II	III	IV	V	VI–II	
Aug.–Sept. 1996	Females	25.0	75.0	0	0	0	4
	Males	0	33.3	66.7	0	0	9
Sept.–Oct. 2001	Females	83.3	16.7	0	0	0	6
	Males	57.1	28.6	14.3	0	0	7
Aug. 2002	Females	7.3	7.3	9.1	12.7	63.6	55
	Males	18.2	45.5	9.1	0	27.3	11
Oct.–Nov. 2004	Females	15.2	60.6	24.2	0	0	33
	Males	12.9	64.5	22.6	0	0	31
July–Aug. 2008	Females	13.6	33.9	29.0	0	0	38
	Males	10.4	29.2	60.4	0	0	26

at *FL* 17 cm and at the age 3–4 years; the females, at *FL* 19–35 and 29 cm and at the age 8–9 years, respectively (Fadeev, 1987).

In the western Bering Sea, the yellowfin sole spawns from June through early August at the water temperature of 1–4°C at the depths of less than 50 m; sometimes, the spawning ends in late August–early September (Pertseva-Ostroumova, 1961). According to our data, recently spawned and still spawning specimens were observed in August during the cold years. Most of the males (67%) in July–November were carrying the gonads of IV stage; the ratio of females with such gonad state did not exceed 29% (Table 12).

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Translated by D. Martynova