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Relation between Biological Parameters of Pacific Salmons of the Genus *Oncorhynchus* and Their Population Dynamics Off the Northeastern Kamchatka Peninsula

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Abstract—Results are provided of a 7-year study of biological parameters in females of three Pacific salmons of the genus *Oncorhynchus* (pink salmon *O. gorbuscha*, chum salmon *O. keta*, and sockeye salmon *O. nerka*) in the Olyutorsky and Karaginsky gulfs, Bering Sea. Abundance of the pink salmon is identified as the main determining factor of the interannual dynamics of maturity index in female Pacific salmon in coastal waters. Maturity index rises at high levels of abundance as a result of differently directed changes in two parameters: decreasing body weight and increasing ovary weight. In female chum salmon, maturity index depends on the age structure of the population and body weight dynamics of different age groups, factors influenced by high abundance of some pink salmon generations, and does not depend on the abundance of spawning chum salmon. The revealed association between pink salmon and sockeye salmon in dynamics of their biological parameters may result from the similarity of their diets; during the last year of fattening in the sea, the sockeye salmon is affected by the pink salmon, the most abundant of the three species. The interannual variation of biological parameters in pink salmon and chum salmon is more pronounced in Olyutorsky Gulf than in Karaginsky Gulf.

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Keywords: Pacific salmons of the genus *Oncorhynchus*, northeastern Kamchatka Peninsula, interspecific relations, female maturity index

INTRODUCTION

At present, the supplies of Pacific salmon of the genus *Oncorhynchus* are constantly high. The annual catch of these salmon off Far Eastern Russia over recent decade varied from 250000 to 540000 tons. Commercial fishing for salmon takes place over a huge area, from the Chukchi Peninsula to Primorye, including the areas off Sakhalin Island, the Kuril Islands, and Commander Islands. The abundance of salmon in different areas of the Russian Far East considerably varies. The northeastern Kamchatka Peninsula is one of the largest centers of breeding for abundant Pacific salmon species (pink salmon *O. gorbuscha*, chum salmon *O. keta*, and sockeye salmon *O. nerka*) in the Asian part of their range. Thus, the annual catch of the pink salmon in this area during the period from 2000 to 2013 peaked in 2011 at 178000 tons. The catches of the chum salmon and sockeye salmon also remained high. The annual catch of the chum salmon peaked (at 15000 tons) in 2013; the annual catch of the sockeye salmon peaked (at 2700 tons) in 2009.

Considering the scale of fishing and the commercial value of the fish, monitoring and control of the catches of Pacific salmons is an important and topical problem for the fishing industry. One of the methods of such monitoring is to estimate how close actual catches are to limits set by companies for standard parameters of production levels, including the parameter of “hard roe yield.” In biological terms, the hard roe yield corresponds to the weight of ovaries at particular stages of their development (III, III–IV, IV, and IV–V). These standards were based on statistics provided by fishing companies for particular Pacific salmon species over large commercial fishing areas, such as off the eastern Kamchatka (*Normy*..., 2010). However, the interannual and seasonal changes observed in the biological structure and abundance of particular salmon shoals within this large region make it necessary to develop more detailed standards for particular parts of the fishing area off northeastern Kamchatka. This is especially important for the three abundant species of Pacific salmon breeding in this area: the pink salmon, chum salmon, and sockeye salmon (Bugaev, 1995, 2011; Bugaev and Kirichenko, 2008; Zavarina, 2008; Antonov, 2011; Klovach and El’nikov, 2013b). In the future, such standards may be developed also for nonabundant species, such as the Chinook salmon *O. tschawytscha* and coho salmon *O. kisutch*, which are also subject to commercial fishing in the areas of the Karaginsky and Olyutorsky gulfs (Zorbidi, 2010; Klovach et al., 2011).

It is well known that the pink salmon is represented by two reproductively isolated lines of even-year and odd-year breeders, considerably different in abundance in most areas. For instance, the catch of the pink salmon off northeastern Kamchatka from 2000 to 2013 in odd years was, on average, 14 times as high as in even years. In years of high abundance, the pink salmon strongly affects biological parameters via food supplies both of its own and of other salmon species fattening together with it in the ocean (Bugaev, 1995; Volobuev, V.V. and Volobuev, M.V., 2000; Klovach, 2003; Volobuev and Marchenko, 2011; Karpenko et al., 2013; Klovach et al., 2013; El'nikov and Gritsenko, 2014). Hence, it is necessary to determine the relation between the interannual dynamics of such integral parameter as the hard roe (ovary) yield to abundance and biological parameters of Pacific salmon in different area. The possibility that this parameter can be used to estimate the size of Pacific salmon catches makes this challenge especially important (Gritsenko and El'nikov, 2013).

It is clear that the value of the hard roe yield is ultimately determined by the proportion of females in catches and by the degrees of their maturity. Although the sex ratio considerably changes during the fishing season, but remains approximately unchanged interannually, the degrees of female gonad maturity, usually estimated by the maturity index (MI), shows considerably smaller seasonal variation and remains almost unchanged over long periods of the spawning migration. Therefore, the sex ratio cannot be used as an indicator of intrapopulation processes that determine the interannual dynamics of the hard roe yield.

The purpose of this study was to characterize the dynamics and determining factors of MI in females of different species of Pacific salmon that breed in basins of rivers that flow into the Olyutorsky and Karaginsky gulfs of the Bering Sea (off northeastern Kamchatka) during periods of different abundance and biological parameters of breeder salmon.

MATERIALS AND METHODS

We studied breeder individuals of Pacific salmon collected over 7 years in two areas off the northeastern Kamchatka Peninsula, in the Olyutorsky and Karaginsky gulfs; the former, according to some authors (Antonov and Balueva, 2000; Antonov et al., 2005; Antonov and Balueva, 2001), lies on the periphery of the East Kamchatka range of the pink salmon and chum salmon, whereas the latter belongs to one of the centers of breeding of these two species. The sockeye salmon abundantly breeds in the basins of some rivers of these areas (Bugaev, 1995; Bugaev and Kirichenko, 2008; Klovach and El'nikov, 2013b). In 2007–2010, this study covered only the Olyutorsky area; during the spawning migrations of 2011–2013, it was performed in both areas simultaneously. The sample sizes, areas, and periods during which the materials were collected are given in the table.

In the Olyutorsky area, the fish were collected from catches of fixed gillnets set in Olyutorsky Gulf northwest and southeast of the mouth of the Apuka River (Fig. 1a) and from catches of nets and sweep seines in the lower reaches of this river (at 13.0–16.5 km from the mouth). In Karaginsky Gulf, the fish were collected only from catches of fixed gillnets set inside and outside the Ossora Bay and off Karaginsky Island (Fig. 1b). The abundance of breeding salmon in each year was estimated based on official statistics of catches.

Random samples of each salmon species were taken from the catches for study. Biological analysis was performed by the standard method (Pravdin, 1966). The total body weight, sex, maturity stage, gonad weight, fecundity, and maturity index were determined. The fecundity of females was determined by the weight method: all eggs were counted in a 15–20 g sample from the central part of one hard roe (Vilenskaya and Markevich, 1988). The maturity index (MI) was calculated as the percentage of the gonad weight in the body weight of the fish.

The data were mathematically processed in the StatSoft Statistica v. 6.0 and MS Excel 2010 programs.

RESULTS AND DISCUSSION

Pink salmon. Interannual changes in the abundance of adjacent generations of the pink salmon in northeastern Kamchatka had opposite directions. The density of the odd-year generation increased from the early 1990s and peaked in 2009 and 2011; in 2013, the abundance of breeders and catches considerably decreased compared to the previous two cycles (Fig. 2). The abundance of the even-year generation changed over the last few decades within a rather narrow range. This is probably the reason for the interannual variation of the average female weight of the pink salmon in odd years and, by contrast, the stability of this parameter in even-year females (Figs. 3a and 3b). The ovary weight, a character more variable ($CV = 22.9\%$) than the female body weight ($CV = 15.7\%$), proved more stable interannually (Figs. 3c and 3d).

In the opinion of Smirnov (1975), increasing abundance of the pink salmon leads to slower maturation of individuals during fattening, later spawning migration of breeders, and, as a result, increase in the degrees of their maturity. However, our observations showed that, in 2009, when the abundance of pink salmon in the Olyutorsky area was almost twice as high as in 2007 (Fig. 2), and their body weight (Fig. 3a) and gonad weight (Fig. 3c) synchronously decreased, their MI did not increase (11.8 in 2007 and 11.7 in 2009) (Fig. 3e), whereas the female body weight continued to decrease in 2011, but the ovary weight remained relatively stable, and the average value of MI increased to 13.3 (Fig. 4); the

Periods and areas of fieldwork and sizes of samples

Species	Gulf	Period of fieldwork	Number of fish, ind.		
			biological analysis		fecundity
			females	males	
Pink salmon	Olyutorsky	July 10–July 29, 2007	273	227	–
	The same	June 22–July 28, 2008	290	309	–
	″	July 7–July 27, 2009	51	49	–
	″	June 19–July 25, 2010	340	331	–
	″	July 4–July 29, 2011	293	307	116
	″	July 10–July 24, 2012	104	58	–
	″	June 22–July 31, 2013	253	212	253
	Karaginsky	July 6–Aug. 5, 2011	710	852	–
	The same	July 10–July 28, 2012	236	292	38
	″	July 3–July 31, 2013	691	548	168
Chum salmon	Olyutorsky	July 10–Aug. 1, 2007	218	332	–
	The same	June 25–Aug. 18, 2008	598	602	–
	″	July 9–July 26, 2009	62	38	–
	″	June 8–Aug. 6, 2010	391	390	–
	″	June 3–Aug. 3, 2011	379	353	208
	″	July 11–July 25, 2012	70	66	–
	″	June 15–July 31, 2013	169	133	167
	Karaginsky	July 5–Aug. 6, 2011	111	107	–
	The same	July 10–July 26, 2012	145	135	38
	″	July 3–July 31, 2013	255	263	158
Sockeye salmon	Olyutorsky	July 9–July 29, 2007	72	40	–
	The same	June 18–July 1, 2008	293	207	–
	″	July 9–July 26, 2009	54	26	–
	″	May 26–July 31, 2010	603	534	–
	″	June 3–Aug. 3, 2011	670	582	181
	″	June 30–July 16, 2012	33	11	–
	″	June 14–July 23, 2013	142	70	122
	Karaginsky	July 5–July 11, 2011	13	6	–
	The same	July 10–July 26, 2012	53	22	40
	″	July 5–July 31, 2013	52	27	–

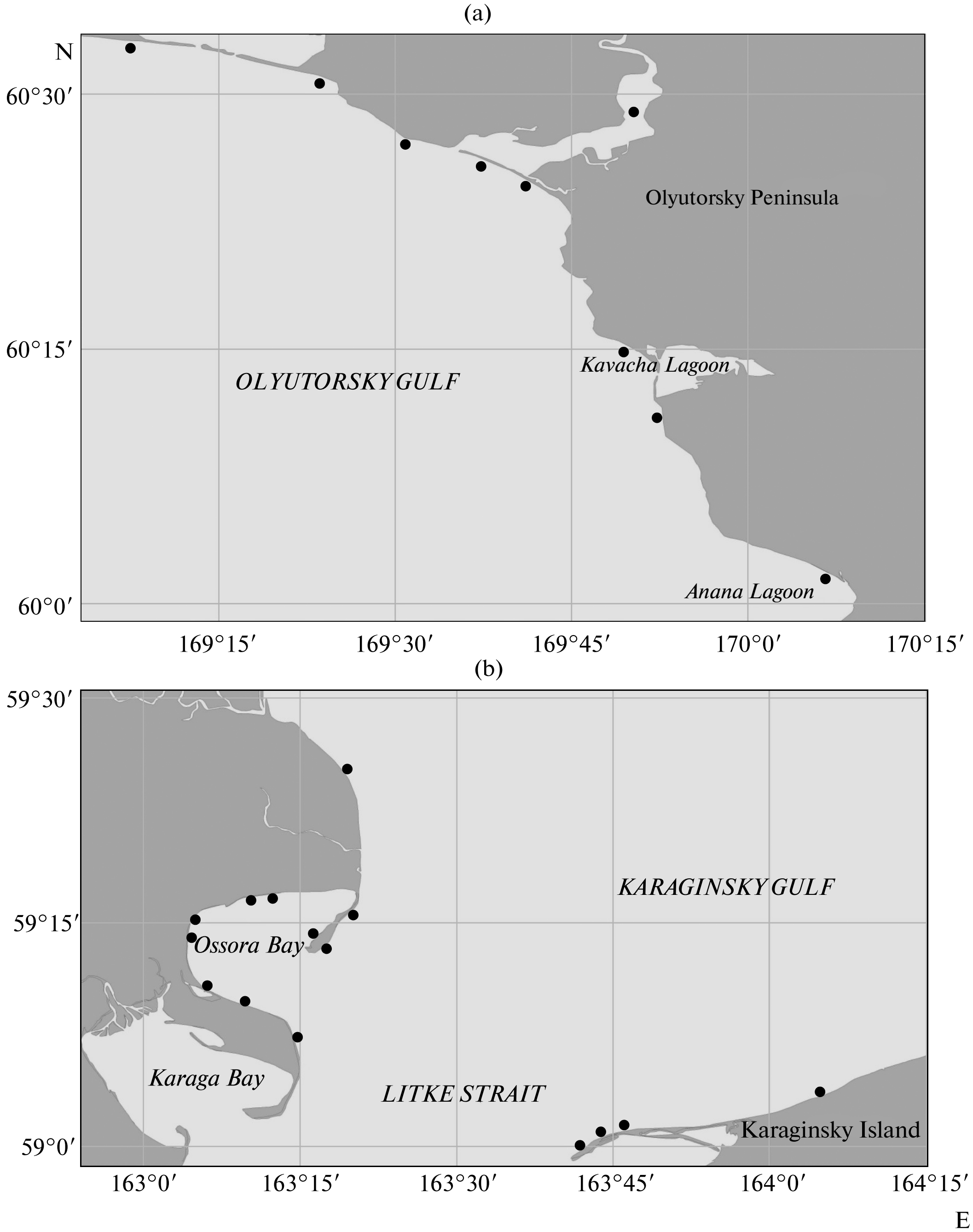

Fig. 1. Schematic map of the position of commercial fishing areas (●) in the (a) Olyutorsky and (b) Karaginsky gulfs.

maximum of the variation series shifted to the right (Fig. 4a). In 2013, the female body weight, ovary weight, and fecundity all increased (the latter from 1303 ± 24 to 1528 ± 16 eggs), but MI was lower (12.5). In our opinion, this increase in fecundity and ovary weight was associated with the 2013 decrease in abundance.

In the even-year generation, the average female body weight and ovary weight remained relatively stable, because of the lower abundance of this generation and, as a result, the smaller influence of the factor of density during the marine period of life. MI changed little: it was 12.1, 12.3, and 11.9, respectively, in 2008, 2010, and 2012 (Fig. 3f).

The interannual changes in the female body weight and ovary weight in pink salmon of Karaginsky Gulf had a similar pattern (Figs. 5a and 5b). The absolute fecundity of the females was, on average, 1359 ± 39 eggs in 2012 and 1454 ± 23 eggs in 2013. A higher maximum value of MI resulting from changes in abundance

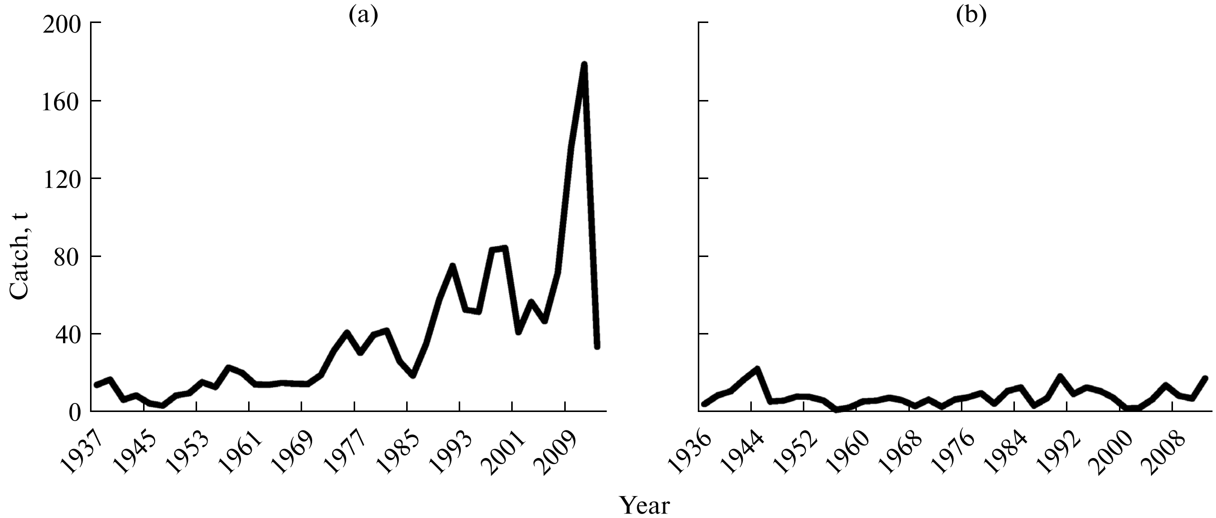

Fig. 2. Catch of pink salmon *Oncorhynchus gorbuscha* off the northeastern Kamchatka Peninsula in (a) odd and (b) even years, 1936–2013.

was recorded only in 2011 (Fig. 4b); this shift was similar to that recorded in Olyutorsky Gulf, but less pronounced. The maximum MI values in female pink salmon in Karaginsky Gulf were, on the whole, somewhat shifted to the left, probably indicating the lower relative fecundity of females in this gulf. No increase in MI was observed in 2013 (Fig. 5c). These differences may reflect the differences in conditions under which pink salmon breed in the two areas.

Thus, the results of our 7-year study have shown that the female body weight of the odd-year generation in pink salmon varies as a result of changes in abundance over a relatively broad range, whereas it remains relatively stable in the even-year generation. At the same time, the average ovary weight can increase in odd years, but it remains almost stable over long periods of time in even years (Figs. 3e, 3f, and 5c). We can conclude from this that the value of MI in pink salmon is influenced by two differently directed factors: the decreasing body weight at higher abundance and increasing fecundity and ovary weight at lower abundance. In the Olyutorsky area, these changes were more pronounced than in the Karaginsky area.

Chum salmon. The abundance (catches) of chum salmon off the northeastern Kamchatka Peninsula, on the whole, increased from 2007 to 2013 (Fig. 6). In years of low pink salmon abundance (i.e., odd years), chum salmon in catches were especially abundant; there were two such years within our study period, 2008 and 2010 (Klovach et al., 2013).

We have found no relation between the degrees of maturity of females and the abundance of breeders. At the same time, the relation of MI of females to their body weight and gonad weight manifested itself indirectly in their age structure. It was noted earlier that when the total abundance of Pacific salmon increases, the proportion of 5-year-old chum salmon breeders also increases, while the proportion of 4-year-old chum salmon breeders decreases (Zavarina, 2008). We observed the same phenomenon in the Olyutorsky area (Klovach et al., 2013; El'nikov and Gritsenko, 2014). In odd years, the proportion of 4-year-old breeders increased, whereas 5-year-old breeders were markedly dominant in even years. This probably results from the stronger competition for food in years of high pink salmon abundance (i.e., odd years), which forces a large proportion of chum salmon breeders to remain in the sea and return for spawning only when they are one year older (Klovach and El'nikov, 2013a). The lowest abundance of breeder chum salmon over the 7 years of this study was recorded in the year of the highest pink salmon abundance (2011), and the smallest female body weight was recorded the next year (simultaneously with the highest proportion, 85%, of 5-year-old breeders). Consequently, the decrease in the average body weight in chum salmon recorded in 2012 resulted from a decrease in the average body weight of almost all age groups, rather than from an increase in the proportion of individuals of younger age groups. The low catch of 2011 probably caused by a 1-year delay in the maturation of a considerable proportion of individuals as a result of the high pink salmon abundance in that year and the effect of density, rather than by low chum salmon abundance. This suggestion is supported by the sharp increase in chum salmon catches recorded in 2012.

The determining factors of MI in chum salmon are different from those in pink salmon (Fig. 7). In female chum salmon, the patterns of interannual changes in body weight and ovary weight are identical (Figs. 7a and 7c). The amplitudes of interannual changes in these parameters are greater in chum salmon than in pink salmon. In our opinion, this difference is determined by both the different age structure of catches

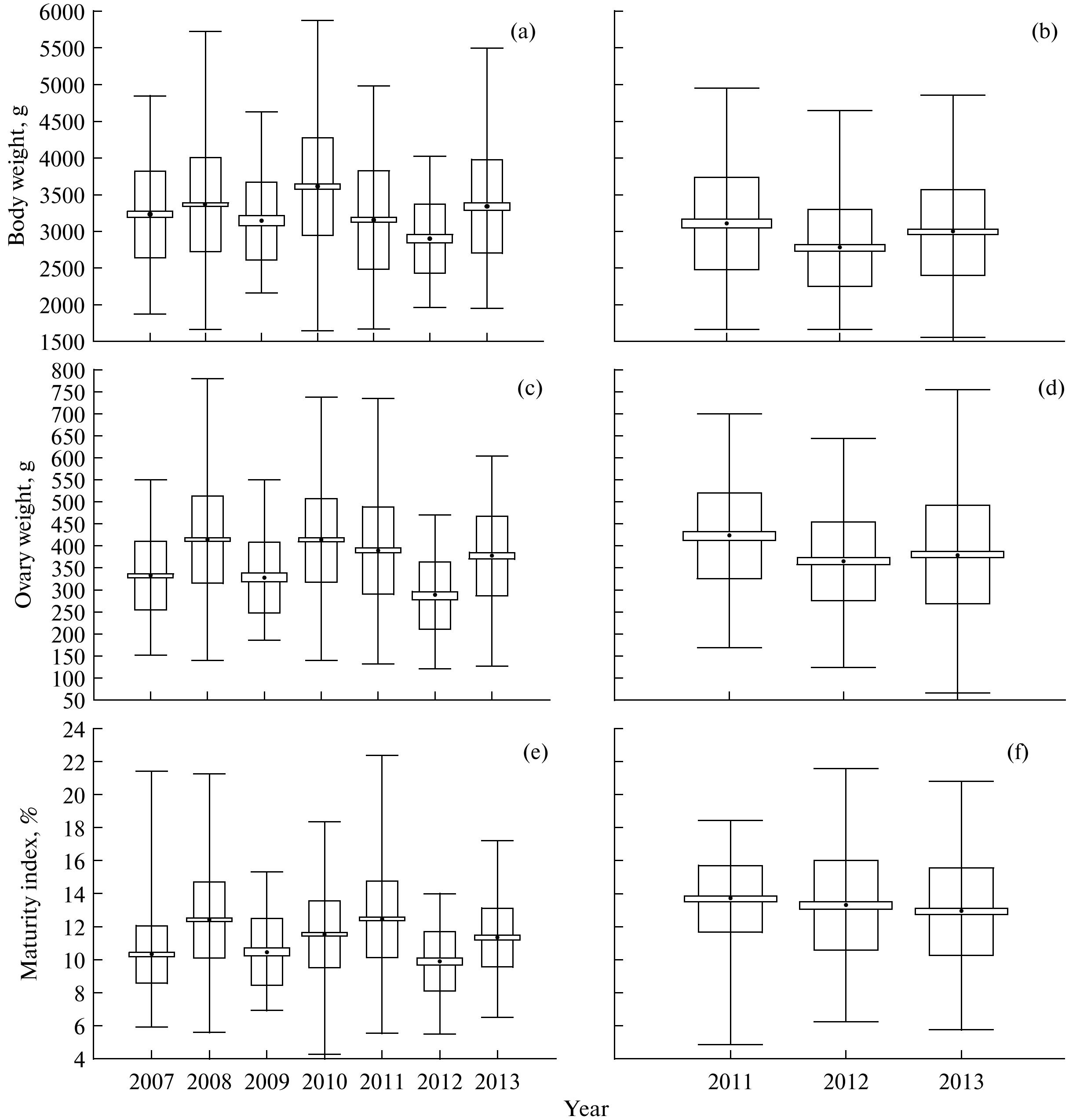

Fig. 3. (a, b) Body weight, (c, d) ovary weight, and (e, f) maturity index in female pink salmon *Oncorhynchus gorbuscha* of Olyutorsky Gulf in (a, c, e) odd and (b, d, f) even years of breeding in 2007–2013: (•) average, (▭) error of average, (□) standard deviation, (⌶) variation range.

and the interannual changes in the body weight of fish of different age (Klovach and El'nikov, 2013a). In addition, two seasonal forms, the earlier and the later, different in biological parameters and spawning ecology, have been distinguished in chum salmon of Olyutorsky Gulf, and their periods of migration into rivers overlap (Klovach and El'nikov, 2013a). Figure 7c shows that the average MI of females decreases in the sequence of even years: from 12.4 in 2008 to 11.5 in 2010 and 9.9 in 2012; by contrast, this parameter gradually decreases in the series of odd years: from 10.3 in 2007 to 10.5 in 2009 to 12.5 in 2011. In our opinion, this is because the average age of breeders was lower in odd years than in even years; hence, the average female body weight was also lower (Fig. 7a). In 2013, when the abundance of breeder pink salmon decreased by a factor of five compared to 2011, the conditions probably became more favorable for chum salmon fattening during the last year of their life in the sea, affecting the average weight this species, which was found to be higher than in earlier odd years, whereas the gonad

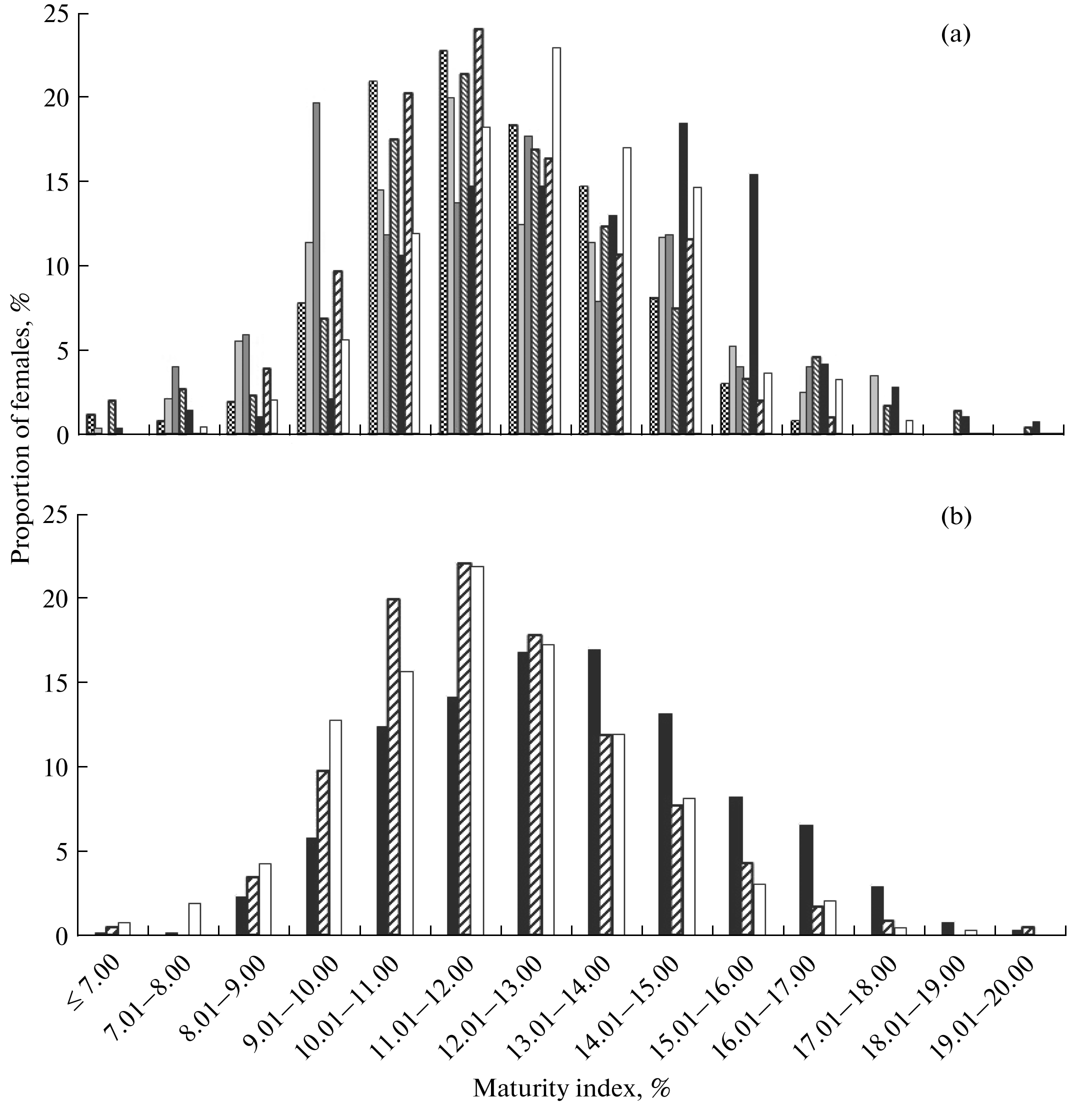

Fig. 4. Distribution of maturity index values in female pink salmon *Oncorhynchus gorbuscha* of the (a) Olyutorsky and (b) Karaginsky gulfs in 2007–2013: (▩) 2007, (▤) 2008, (▦) 2009, (▧) 2010, (■) 2011, (▨) 2012, (□) 2013.

weight remained almost unchanged compared to 2011; as a result, MI decreased to 11.3.

The average values of biological parameters of chum salmon in Karaginsky Gulf are less variable than in Olyutorsky Gulf (Figs. 7b, 7d, and 7f). In our opinion, this difference is determined by the different length of rivers in the two breeding areas. The average length of rivers flowing into Karaginsky Gulf is 92 (69–112) km, while the two main rivers of Olyutorsky Gulf, the Pakhacha and Apuka, are approximately 300 km long. As a result, the breeders that spawn in rivers of Karaginsky Gulf have gonads of rather similar degrees of maturity, while the breeders that spawn in rivers of Olyutorsky Gulf reproduce both in upper spawning areas, dozens or hundreds of kilometers from the coast, and in lower spawning areas, situated near the mouths. It should also be noted that breeders of the later (autumn) form start migrating in Karaginsky Gulf much later than in Olyutorsky Gulf (during the second 10 days of August and second 10 days of July, respectively); as a result, in Karaginsky Gulf the autumn form is almost absent in catches. We have only sporadically observed autumn chum salmon with gonads of maturation stage II–III during the study period; MI of these fish was at most 1.5–3.0.

Thus, in spite of the revealed differences in values and dynamics of biological parameters, chum salmon of the two areas display some common features. The maturity index of females does not depend on the abundance of breeder chum salmon. These parameters are indirectly influenced by the abundance of pink

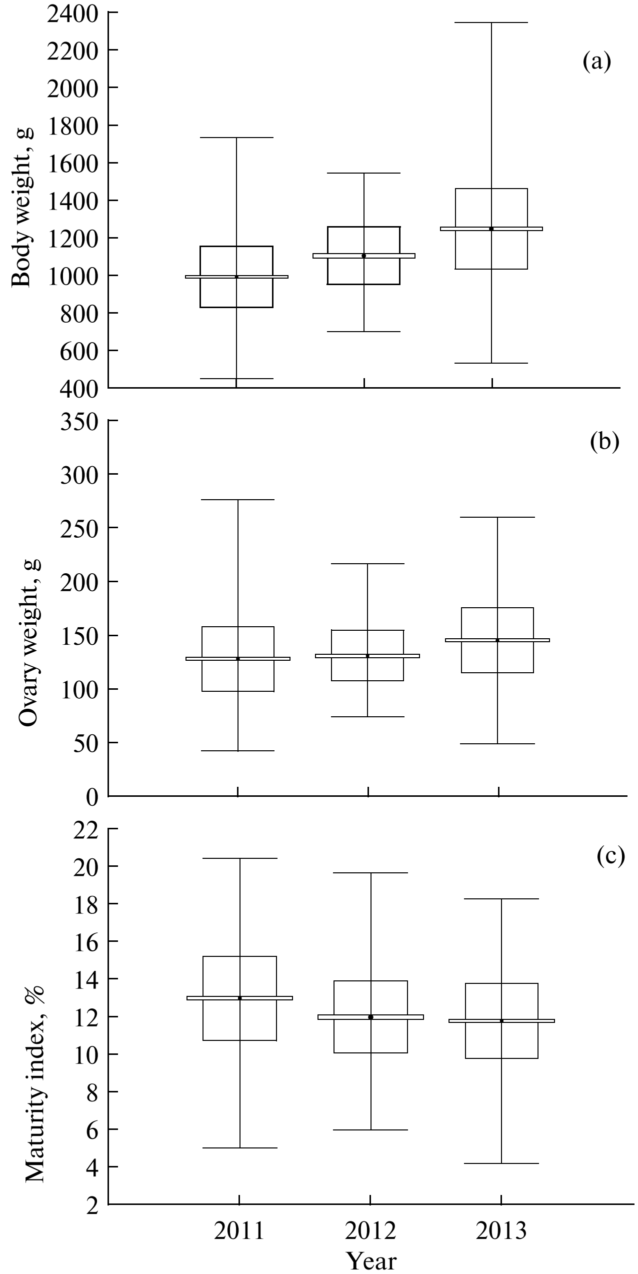

Fig. 5. (a) Body weight, (c) ovary weight, and (e) maturity index in female pink salmon *Oncorhynchus gorbuscha* of Karaginsky Gulf in 2011–2013; notation as in Fig. 3.

salmon, which largely determines the age structure and average body weight of chum salmon.

Sockeye salmon. From 70 to 90% of sockeye salmon living off northeastern Kamchatka breed in the Kamchatka River (Bugaev, 1995, 2011; Bugaev et al., 2007). The abundance of this species in the Karagnisky subzone is relatively low. The highest catches over the study period were recorded in 2009 (Fig. 8). The importance of rivers of the Olyutorsky and Karaginsky gulfs for breeding of sockeye salmon varies from year to year. In the last decade, most sockeye salmon breed

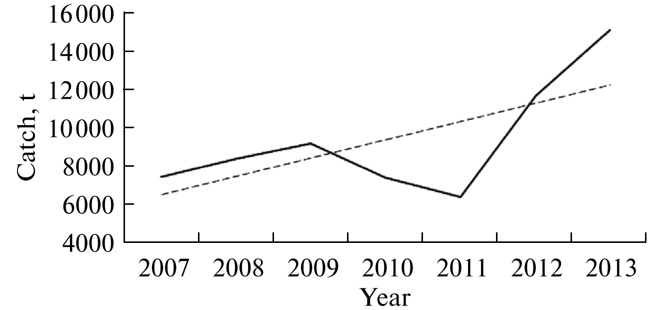

Fig. 6. Catch of chum salmon *Oncorhynchus keta* off the northeastern Kamchatka Peninsula in 2007–2013: (——) data of commercial fishing statistics; (- - -) trend, $y = 958.65x + 5529.4$, $R^2 = 0.4579$.

in basins of rivers flowing into Olyutorsky Gulf (Pogodaev, 2013).

The interannual dynamics of the female body weight and gonad weight of sockeye salmon in Olyutorsky Gulf in 2007–2013 (Fig. 9) were almost identical to those of pink salmon (Figs. 9a, 9c). The only exception was 2012, when the female body weight of sockeye salmon decreased (from 2420 to 2350 g), while their ovary weight increased (from 239 to 260); as a result, the average MI in female sockeye salmon peaked at 11.2 (Fig. 9d). The similarity observed in the dynamics of biological parameters in pink salmon and sockeye salmon may result from the similarity of their diets (Karpenko et al., 2013). We conclude from this that, in spite of the complexity of the age structure of sockeye salmon in the Olyutorsky area (where breeders of this species spend up to 3 years in the river and fatten for 2–4 years in the ocean), the determining factors of MI are conditions under which the fish live during the last year of their marine life, when sockeye salmon are affected by pink salmon, the most abundant of the three Pacific salmon species.

In the Karagnisky area, sockeye salmon breed in several rivers. In some of them, they are rather abundant. The rivers especially important for breeding of the sockeye salmon include the Rusakova, Khailyulya, Ivashka, Vyvenka, Dranka, Tymlat, Karaga, Kichiga, and Belaya (Bugaev, 1995, 2011; Pogodaev, 2013). We sampled fish from fixed gillnets set near the mouths of other rivers of Karaginsky Gulf and Karagnisky Island, in which sockeye salmon do not breed, i.e., in those areas in which sockeye salmon were fished as by-catch of commercial fishing for pink salmon and chum salmon. Since these areas were remote from breeding areas of sockeye salmon, individuals with gonads at maturation stages III and III–IV were dominant in the samples (50–89%). Female sockeye salmon from Karaginsky Gulf weighed, on average, 270 g more than those from Olyutorsky Gulf (Fig. 9b), but their average ovary weight was smaller by 22 g because of the rather

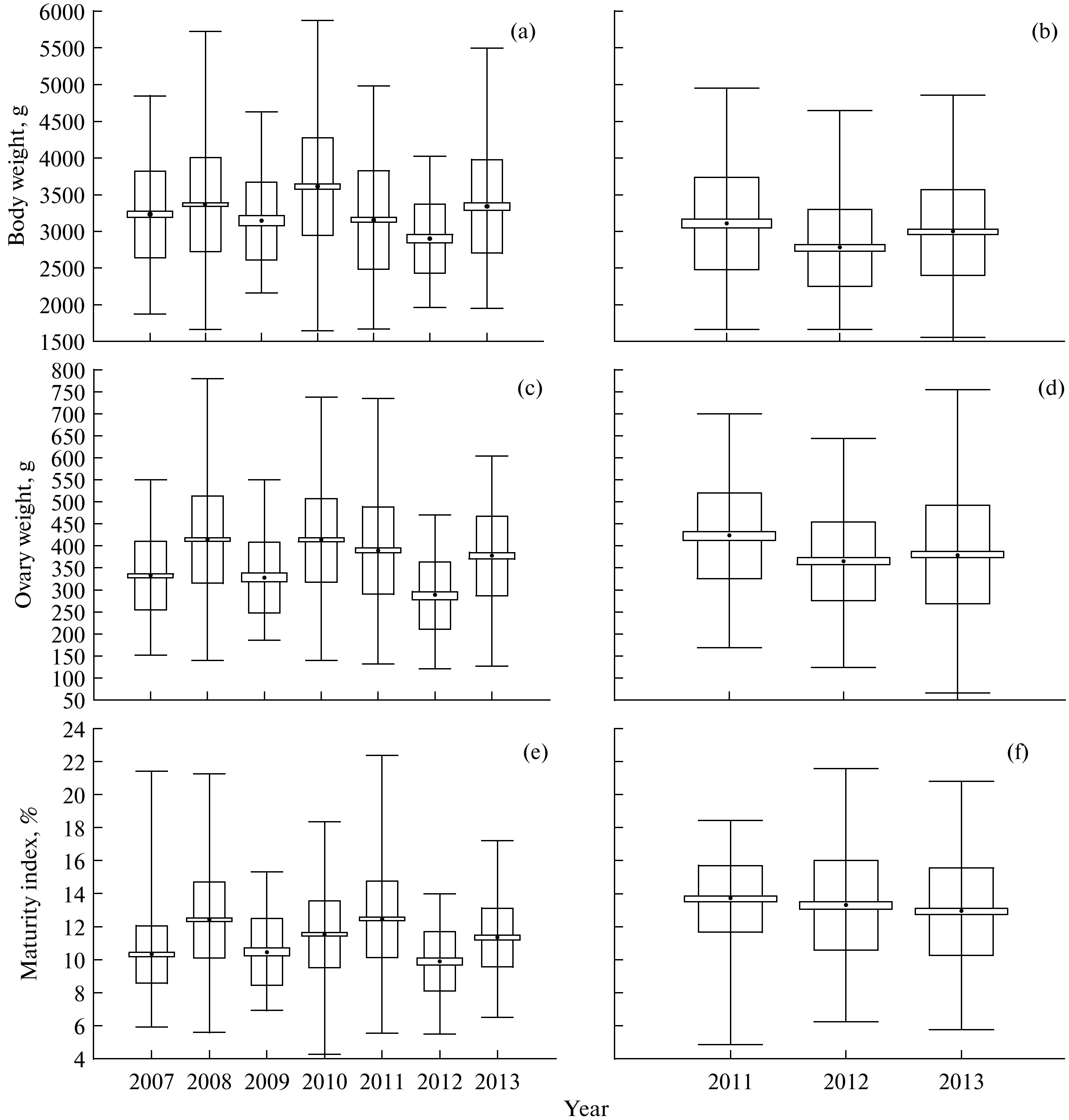

Fig. 7. (a, b) Body weight, (c, d) ovary weight, and (e, f) maturity index in female chum salmon *Oncorhynchus keta* of (a, c, e) Olyutorsky Gulf and (b, d, f) Karaginsky Gulf in 2007–2013; notation as in Fig. 3.

low degrees of gonad maturity (Fig. 9d); as a result, the average values of MI reached at most 7.7–9.4 (Fig. 9f).

The observed similarity in MI dynamics of breeder sockeye salmon of the two areas may indicate that the conditions under which fish of these species mature in different areas off the northeastern Kamchatka Peninsula; at the final stage of the life cycle, these conditions largely depend on the abundance of pink salmon. Some differences in interannual dynamics of the female body weight and ovary weight of sockeye salmon may result from the heterogeneity of catches, which include individuals of two seasonal groups in Olyutorsky Gulf (Klovach and Roi, 2010; Klovach and El'nikov, 2013b) and breeders migrating into different rivers in Karaginsky Gulf.

CONCLUSIONS

Studies performed in two areas off the northeastern Kamchatka Peninsula have revealed several factors that determine the interannual dynamics of maturity

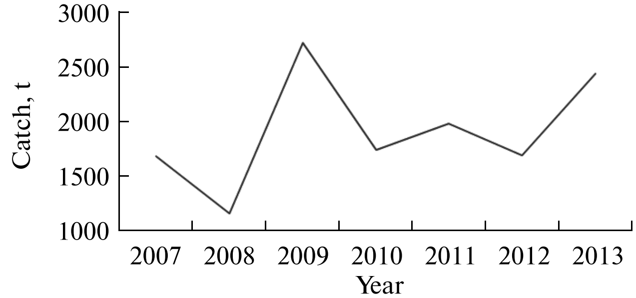

Fig. 8. Catch of sockeye salmon *Oncorhynchus nerka* off the northeastern Kamchatka Peninsula in 2007–2013: (—) data of commercial fishing statistics.

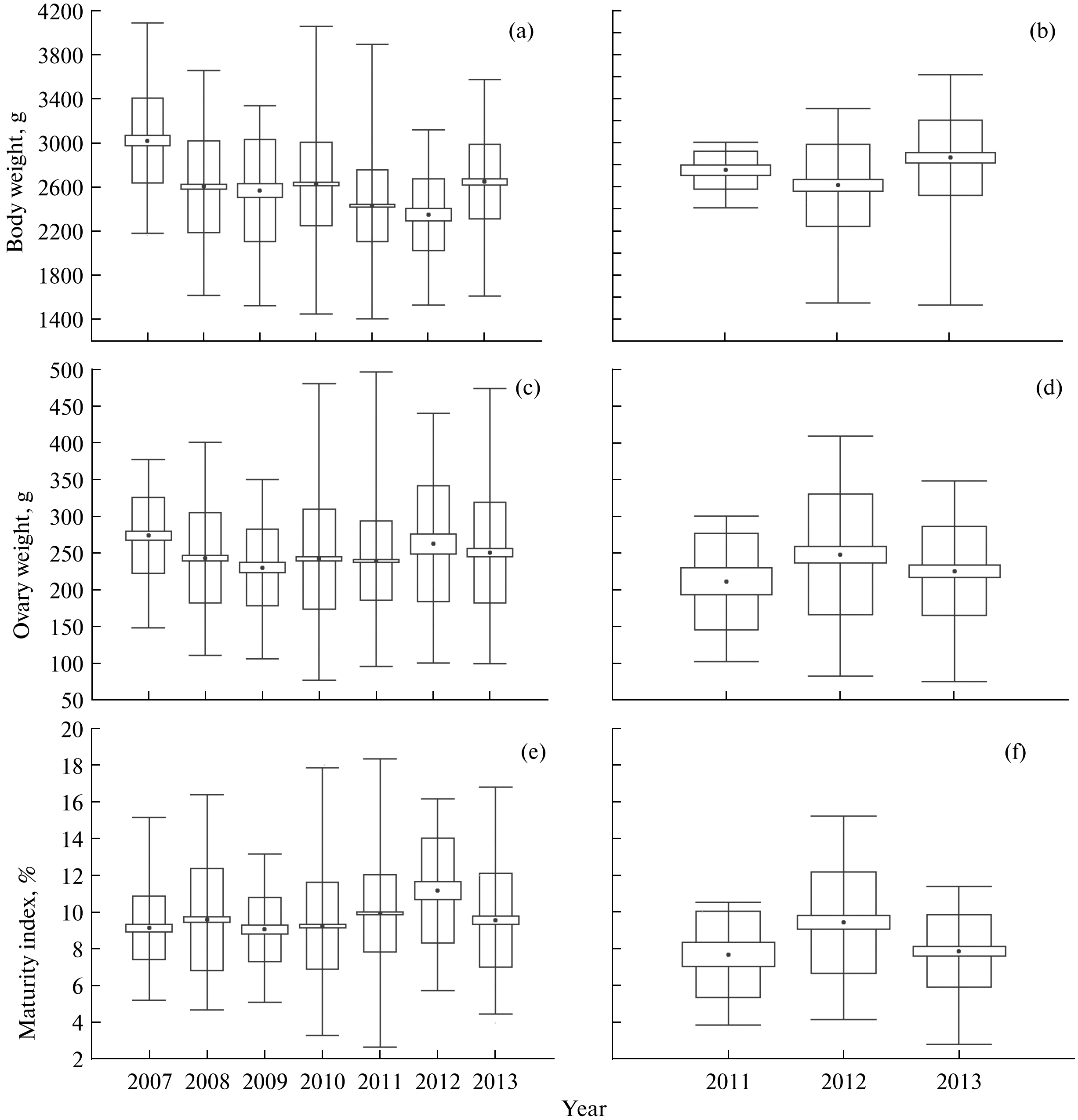

Fig. 9. (a, b) Body weight, (c, d) ovary weight, and (e, f) maturity index in female sockeye salmon *Oncorhynchus nerka* of (a, c, e) Olyutorsky Gulf and (b, d, f) Karaginsky Gulf in 2007–2013; notation as in Fig. 3.

index in female Pacific salmons and their maturation specifics.

For the pink salmon, the most abundant of the three Pacific salmon species, the main factors are the abundance of adjacent generations and the density of salmon during their prespawning fattening; the latter factor is related to the former. An abundant odd-year generation affects the variation of biological parameters in the pink salmon and other species. Nonabundant even-year generations of the pink salmon have relatively stable biological parameters, because they weakly depend on density. Therefore, the value of the maturity index (and, thus, of the hard roe yield) is influenced by two differently directed factors: decreasing body weight at higher abundance and increasing fecundity and ovary weight at lower abundance.

For the chum salmon, in contrast to the pink salmon, the determining factor is not the abundance of spawning individuals but the age structure of the population and body weight dynamics of different age groups, factors that vary under indirect influence of abundant pink salmon generations. The interannual variation of biological parameters in both the chum salmon and pink salmon is more pronounced on the periphery of the range than in the center of breeding.

The dynamics of biological parameters of the sockeye salmon in the year of its spawning migration are considerably influenced by the pink salmon, because of the similar diets of the two species.

The chum salmon is the most variable of the three salmon species in body weight, gonad weight, and maturity index. At the same time, the interannual dynamics of the studied parameters in the pink salmon and sockeye salmon are similar, although the age structures of breeders are different.

The results make it possible to recommend dividing the standard normative hard roe yield parameter for the pink salmon into two parameters, one for even and one for odd years of breeding. At the same time, we should take into account the interrelatedness of the maturity index dynamics (and, thus, the hard roe yield dynamics) of the pink salmon and sockeye salmon.

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REFERENCES

Antonov, N.P., *Promyslovye ryby Kamchatskogo kraya: biologiya, zapasy, promysel* (Commercial Fish Species of Kamchatka: Biology, Reserves, and Fishery), Moscow: VNIRO, 2011.

Antonov, N.P. and Balueva, E.S., Identification of the pink salmon *Oncorhynchus gorbuscha* (Walbaum) from mixed marine catches using the scale structure, *Sb. Nauch. Tr. Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.*, 2000, vol. 5, pp. 51–55.

Antonov, N.P. and Balueva, E.S., Space-time structure of pink salmon of the North-Western Pacific Ocean, in *Proc. of the 20-th Northeast Pacific Pink and Chum Salmon Workshop*, Washington, 2001.

Antonov, N.P., Zorbidi, Zh.Kh., and Balueva, E.S., Comparison of intraspecific diversity of pink salmon *Oncorhynchus gorbuscha* (Walb.) and coho salmon *O. kisutsch* (Walb.) from northwestern Pacific using scale structure, *Sb. Nauch. Tr. Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.*, 2005, vol. 1, pp. 160–167.

Bugaev, V.F., *Aziatskaya nerka (presnovodnyi period zhizni, strucktura stad, dinamika chislennosti)* (Asian Sockeye Salmon: Freshwater Life Cycle, Structure of Local Herds, and Population Dynamics), Moscow: Kolos, 1995.

Bugaev, V.F., *Aziatskaya nerka-2 (biologicheskaya stryktura i dinamika chislennosti lokal'nykh stad v kontse XX – nachale XXI vv.* (Asian Sockeye Salmon-2: Biological Structure and Population Dynamics of Local Herds in the End of 20th – Beginning of 21st Centuries), Petropavlovsk-Kamchatskii: Kamchatpress, 2011.

Bugaev, V.F. and Kirichenko, V.E., *Nagul'no-nerestovye ozera aziatskoi nerki (vklyuchaya nekotorye vodoemy areala)* (The Lakes of the Fattening-Spawning of Asian Sockeye Salmon Including Other Reservoirs of Habitat), Petropavlovsk-Kamchatskii: Kamchatpress, 2008.

Bugaev, V.F., Vronskii, B.B., Zavarina, L.O., et al., *Ryby reki Kamchatka* (Fishes of the Kamchatka River), Petropavlovsk-Kamchatskii: Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr., 2007.

Elnikov, A.N. and Gritsenko, A.V., Changes of biological features of farmers of Pacific salmons of genus *Oncorhynchus* in Apuka River and Olutorsky Bay, Bering Sea in 2007–2012, in *Issledovaniya vodnykh biologicheskikh resursov Kamchatki i severo-zapadnoi chasti Tikhogo okeana* (Study of Aquatic Biological Resources of Kamchatka and Northwestern Pacific), Petropavlovsk-Kamchatskii: Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr., 2014, vol. 33, pp. 5–14.

Gritsenko, A.V. and Elnikov, A.N., Assessment of the catch volume of Pacific salmons by the yield of eggs, *Rybn. Khoz.*, 2013, no. 2, pp. 65–70.

Karpenko, V.I., Andrievskaya, L.D., and Koval', M.V., *Pitanie i osobennosti rosta tikhookeanskikh lososei v morskikh vodakh* (Nutrition and Growth Peculiarities of Pacific Salmons in Marine Waters), Petropavlovsk-Kamchatskii: Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr., 2013.

Klovach, N.V., *Ekologicheskie posledstviya krupnomasshtabnogo razvedeniya kety* (Environmental Consequences of the Large-Scale Farming of Shum Salmon), Moscow: VNIRO, 2003.

Klovach, N.V. and El'nikov, A.N., Structure of spawning school of chum salmon *Oncorhynchus keta* from Olutorsky Bay of the Bering Sea (Northeastern Kamchatka), *J. Ichthyol.*, 2013a, vol. 53, no. 9, pp. 720–730.

Klovach, N.V. and Elnikov, A.N., Structure of spawning of the sockeye salmon (*Oncorhynchus nerka*) herd of Apuka River (northeastern Kamchatka), in *Issledovaniya vodnykh biologicheskikh resursov Kamchatki i severo-zapadnoi chasti Tikhogo okeana* (Study of Aquatic Biological Resources of Kamchatka and Northwestern Pacific), Petropavlovsk-Kamchatskii: Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr., 2013b, vol. 30, pp. 39–43.

Klovach, N.V., Elnikov, A.N., and Gritsenko, A.V., Structure of spawning stocks of four Pacific salmon species of the Olutorsky Bay (Bering Sea, North-East Kamchatka), in *NPAFC Document No. 1488*, 2013.

Klovach, N.V., El'nikov A.N., and Roi, V.I., Characteristics of the spawning stock of Chinook salmon *Oncorhynchis tshawytscha* from the Apuka River (northeastern Kamchatka), *J. Ichthyol.*, 2011, vol. 51, no. 9, pp. 758–768.

Klovach, N.V. and Roi, V.I., Structure of the school of sockeye salmon *Oncorhynchus nerka* from the Apuka River (the northeastern Kamchatka), *J. Ichthyol.*, 2010, vol. 50, no. 6, pp. 460–464.

Normy otkhodov, poter', vykhoda gotovoi produktsii i raskhody syr'ya pri proizvodstve ikry tikhookeanskikh lososei Dal'nevostochnogo basseina (Standards of Wastes, Losses, Final Production, and Raw Material Spends during Caviar Production of Pacific Salmons), Moscow: TINRO-Tsentr, 2010.

Pogodaev, E.G., Spatial distribution and population dynamics of local herds of sockeye salmon in northern fishery regions of Kamchatka krai, in *Issledovaniya vodnykh biologicheskikh resursov Kamchatki i severo-zapadnoi chasti Tikhogo okeana* (Study of Aquatic Biological Resources of Kamchatka and Northwestern Pacific), Petropavlovsk-Kamchatskii: Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 2013, vol. 30, pp. 28–38.

Pravdin, I.F., *Rukovodstvo po izucheniyu ryb* (Handbook on Fish Study), Moscow: Pishchevaya Promyshlennost', 1966.

Smirnov, A.I., *Biologiya, razmnozhenie i razvitie tikhookeanskikh lososei* (Biology, Reproduction, and Development of Pacific Salmons), Moscow: Mosk. Gos. Univ., 1975.

Vilenskaya, N.I. and Markevich, N.B., Determination of fertility by weight method by example of salmons, *Vopr. Ikhtiol.*, 1988, vol. 28, no. 1, pp. 159–163.

Volobuev, V.V. and Marchenko, S.L., *Tikhookeanskie lososi kontinental'nogo poberezh'ya Okhotskogo morya (biologiya, populyatsionnaya struktura, dinamika chislennosti, promysel)* (Pacifc Salmons of Continental Coast of the Sea of Okhotsk: Biology, Population Structure and Dynamics, and Fishery), Magadan: Sev.-Vost. Nauchn. Tsentr, Dal'nevost. Otd., Ross. Akad. Nauk, 2011.

Volobuev, V.V. and Volobuev, M.V., Ecology and structure of populations as the general elements of life strategy formation of the chum salmon *Oncorhynchus keta* of continental coast of the Sea of Okhotsk, *Vopr. Ikhtiol.*, 2000, vol. 40, no. 4, pp. 516–529.

Zavarina, L.O., Biology and dynamics of (*Oncorhynchus keta*) population at the northeastern coast of Kamchatka, *Extended Abstract of Cand. Sci. (Biol.) Dissertation*, Moscow: VNIRO, 2008.

Zorbidi, Zh.Kh., *Kizhuch aziatskikh stad* (The Coho Salmon from Asian Herds), Petropavlovsk-Kamchatskii: Kamchat. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr., 2010.

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