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Interannual Changes in Anadromous Migrations of Salmons in the Western Bering Sea and Adjacent Pacific Waters

by

V.P. Shuntov, V.V. Lapko,
A.A. Balanov, and A.V. Startsev

Laboratory of Applied Biocenelogy

Pacific Research Institute of Fishery

and Oceanography (TINRO)

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Abstract

The features of anadromous migrations of pacific salmon in anomalous oceanologic conditions in 1993 are observed in the western Bering Sea and adjacent Pacific waters. Most salmon were redistributed to the northern part of the investigated area. Total biomass of salmons decreased more than twice in comparison with same time in 1991 (from 328.60 to 149.07 thousands tons).

This decreasing is conditioned by following reasons:

a) density-dependent factor influence (the parent generation in 1991 was high abundant

b) start of long-term decreasing of salmon abundance,related with the beginning of climate - oceanologic period,similar with 40-60s.

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UDK 597.553.2 (265.53) Ichthyology

INTERANNUAL CHANGES IN ANADROMOUS MIGRATIONS OF SALMONS IN THE WESTERN BERING SEA AND ADJACENT PACIFIC WATERS

V.P. Shuntov, V.V. Lapko, A.A. Balanov, A.V. Startsev

Laboratory of Applied Biocenology,
Pacific Research Institute of Fisheries and
Oceanography, Vladivostok 690600

The peculiarities of the anadromous salmon migrations in the Bering Sea and adjacent Pacific waters under anomalous oceanological conditions in 1993 are considered. The redistribution of essential share of salmons to the more northern waters is noted. As compared with analogous period in 1991, biomass of salmons in the region under consideration has decreased more than two times.

In 1991, PRIFO began using trawling surveys to carry out annual accounting of salmons during anadromous migrations when these fishes approach particular sections of shoreline by extended front. Unprecedentedly extensive information obtained when carrying out these surveys proved to be very useful not only from viewpoint of notions of marine life period of salmons but also for operative forecasting of dates and scales of their spawning migrations (Shuntov et al., 1993, 1993a). Similar investigations have been also performed in summer of 1993. This year has considerably differed from previous ones with respect to oceanological conditions that has caused appropriate response in the composition of the nekton associations and in the distribution of pelagic fishes including salmons. In order to accumulate the sets of observations and experience of estimating ecological situations when the operative forecasting of salmons coming to the shores, it is appropriate to specially consider the peculiarities of anadromous migrations of these fishes under specific conditions in 1993.

MATERIALS AND METHODS

A survey of the western Bering Sea and Kamchatka-Komandorsky waters of the ocean has been carried out under the direction of the first author of this paper from June 20 to July 17, 1993, using research ships "TINRO", "Professor Kizevetter", "Professor Soldatov". As to time periods, this survey has coincided with similar survey in 1991 (June 22-July 12) that provides comparison of data obtained when carrying out these surveys. In 1993, a total of 103 hourly trawlings have been performed within upper 50-m layer in the region under consideration. In all of ships, the trawlings have been performed using rope trawl 108/528 (vertical opening is about 50 m) with speed of 4.5-5.0 knots. For calculations of quantity and biomass of fishes by standard area method, as in the previous expeditions, the catchability coefficient of trawl for salmons equal to 0.3 has been used. All salmons from each trawl have been accounted and subjected to biological analysis with obligatory determination of maturity coefficients (MC) of gonads, composition and filling of stomachs. Generalization of information gathered has been made for earlier accepted (Shuntov et al., 1993) biostatistical regions. The network of trawlings and stations as well as limits of regions can be judged from diagrams given in the paper. Collection and processing of data of plankton have been performed by A.P. Volkov, V.V. Nadtochii, A.Ya. Efimkin and V.I. Lapshina.

When analyzing the distribution of salmons at final stage of their anadromous migrations, it needs to bear in mind that the survey has been carried out from the north and from the shore. This allowed "to cut off" salmons from the offshore waters and eliminated the repeat accounting of the same fishes.

RESULTS

At the beginning of survey in the offshore waters of the Karaginsky-Olyutorsky region where major spawning-grounds of the most mass salmon for the region under consideration - pink salmon (Oncorhynchus gorbuscha) - are located, salmons were few. Their overwhelming bulk was further south and east. In Table 1, the accounted biomass of all species of salmons is given for biostatistical regions shown in Fig.1 A total biomass of all salmons was about 150 thousand tons and one third of it fell on the pink salmon share. As compared with analogous the odd year of 1991, the biomass of salmons decreased approximately 2.2 times. A decline of quantities of pink salmon and chum salmon (Oncorhynchus keta) appeared to be particularly considerable. Only quantity of malma (Salvelinus malma) in 1993 was greater.

Such drastic decrease of quantity of salmons fits well into the course of long-standing dynamics of their quantity in the North Pacific on the whole. In this case, basic tendencies of this course are first of all determined by the dynamics of climatic-oceanological and hydrobiological environment (Chigirinsky, 1993; Beamish, Bouillon, 1993). Now, it is already evident that period of increase and increased quantity of Pacific salmons (1970-1980s) has changed since the beginning of 1990s to period of decreased efficiency of reproduction and production of these fishes. In case of pink salmon, in addition, very high number of spawners in 1991 could play some negative role in forming the generation approaching the spawning-grounds in 1993. Recall that approaches of pink salmon in 1991 to the East Kamchatka fishing region were extremely powerful that is confirmed by data of marine accounts - about 170 thousands tons (Shuntov et al., 19930 - and record commercial catch - 73 thousands tons.

When comparing data of quantitative distribution of salmons in 1991 and 1993, all species show quite considerable differences. In 1991, pink salmon has migrated to the Kamchatka shores by more wide front and, in this case, about 65% of it were accounted to the north of Komandorskie Islands (Shuntov et al., 1993). In 1993, to the south of Komandorskie Islands, pink salmon was few (Fig.2) - only about 14 thousands tons or 25% (Table 1). Judging from sex ratio, in this year, in addition to the north-western trend, the northern trend in its migration has been more clearly traced.

Differences in distribution of other species of salmons were even more pronounced during the years compared. In 1991, more than one half (58% of biomass) of chum salmon quantity was registered in the Pacific waters off Kamchatka. At the same time, to south of the Komandorskie Island, fry and pubescent chum salmon were found in large quantities (Shuntov et al., 1993). In 1993, more than 75% of chum salmon were at the time in the Bering Sea (Table 1). Inclination of non-pubescent individuals (Fig.3) to the northern waters was especially evident.

Redistribution of sockeye salmon (Oncorhynchus nerka) was similar and even more essential. In 1991, about 93% of its biomass has been registered to south of the Komandorskie Islands (Shuntov et al., 1993). In 1993, a distribution of only pubescent fishes has been similar. At the same time, about 60% of fry have been concentrated in the Bering Sea (Fig.4, Table 1).

During 1991 survey, none of coho salmons (Oncorhynchus kisutch) has been caught. In 1993, 0.26 thousands tons of registered 0.94 thousands tons have fallen at the Bering Sea. During both years compared, in the Bering Sea the greater quantity of chum salmon (Oncorhynchus tschawytscha) has been registered than that in the Pacific waters.

Thus, in the quantitative distribution of Pacific salmons during their anadromous migrations, the inclination to more northern regions has been quite clearly traced almost for all species in 1993. A specificity of the year 1993 has clearly presented in some biological indicators, especially for pink salmon. During anadromous migrations of this species, the males predominate, as a rule, in the first waves of fishes moving to the shores while the females predominate at the final stage. In addition, the maturity coefficient and share of more mature fishes progressively increase. Sex ratio for pink salmon in the different sites of the region under consideration has been in agreement with known regularity (Fig.2). A character of pink salmon maturation was at the same time unusual in many respects. Uncommonness of situation lay in the fact that pink salmon both in the front part of migration and in the rearguard (400 miles from the shores) had approximately equal maturity. So, during survey (late June - early July), average maturity coefficient of pink salmon females has been for microregions: 9.0-9.5% in the oceanic waters off the Kamchatka shoreline, 9.5-10.5% to south of Komandorskie Islands, 9.7-10.2% in the Komandor hollow of the Bering Sea, 9.8-10.2% near the Olyutorsky and Karaginsky Bays and 9.7% over the Olyutorsky submarine ridge. These data indicate the concerted (and early on the average) maturation of the greater share of pink salmon of the eastern Kamchatka groups that has been appropriately reflected on the high rate of fish coming to the shores. Catch of pink salmon by fixed nets has begun on June 28 (approximately a week earlier than in 1991), and, on July 7, increasing catch was about 870 t while on July 14 6853 t. During two next weeks, the catch has increased by 15950 t and 16785 t respectively.

Curiously, it was found that once major mass of pink salmon has approached the rivers, its approaches, although less considerable, have been continued throughout August. Moreover, in the second ten-days period, even somewhat increased "splash" of catches has taken place. On the whole, to the catch in July (about 40 thousands tons of pink salmon), further 11 thousands tons were added in August. This point will be touched on in the paper conclusion. Here, it makes sense to touch on the comparatively early and concerted maturation of the greater part of the total number of pink salmon in 1993 within the region under consideration. Explanation for this fact should be, evidently, searched for in the temperature and forage conditions on the paths of the spring-summer migrations. Judging from migrations times and rate of pubescence, the conditions of feeding migration in 1993 were more favourable as compared with 1991. However, this has not been reflected on the pink salmon sizes. In 1991, its average weight was 1.10 kg in the Bering Sea, 1.20 kg in the Pacific waters off the Kamchatka and, in 1993, 1.12 kg and 1.15 kg respectively. In this case as we have earlier mentioned, in 1993, the total number of pink salmon was less than in 1991, much more than two times. The surface water temperature in the Bering Sea last summer had, on the average, increased values according to data of our expedition.

The results of correlation between the biomasses of forage organisms proved to be less unambiguous. Recently, it has been demonstrated that in early 1990s in the majority of the Far-Eastern seas regions, decreasing of the non-predatory plankton biomass has been found but, at the same time, quantity of predatory plankton has increased (Shuntov et al., 1993). In the Bering Sea, this tendency has been evolving in 1993. Average biomass of non-predatory plankton within 0-200 m layer has decreased from 103 to 89 t/km while one of predatory plankton has increased from 74 to 118 t/km that has caused some growth of total biomass of plankton (177 and 207 t/km). In the Pacific waters off the Kamchatka, biomasses of non-predatory and predatory plankton remained approximately at the same level: 48 and 50 t/km for non-predatory plankton and 58 and 43 t/km for predatory one. Increasing biomass of predatory plankton occurred largely at the expense of sagitta which do not play any sufficient role in feeding of salmons. In addition to them, in the Bering Sea and oceanic waters off the Kamchatka, the quantity of giperiids being among the forage organisms preferred by salmons has increased. Fine nekton, in particular, squids have a significant place in feeding of salmons including pink salmon. Biomass of squids within upper 50-m layer in 1993 as compared with 1991 somewhat has increased in the Bering Sea (0.2 and 0.3 t/km) but has decreased in the Pacific waters off the Kamchatka (0.6 and 0.4 t/km).

In summary, it is evident one can say about concentrations of forage organisms that conditions for feeding in 1993 were, on the whole, more favourable, especially in the Bering Sea. In this case, we keep in mind also that the number of pink salmon and salmons on the whole in 1993 was less much more than two times and, in addition, the quantity of basic consumer of macroplankton - wall-eyed pollack - has sufficiently decreased (Shuntov et al., 1993b).

In addition to above it should be presented some data of sizes of the sockeye and chum salmons having more complex age composition. For sets of sockeye salmon sizes, the presence of three peaks is typical which begin to form beginning in previous autumn when sockeye salmon completes downstream migration from fresh waters. In summer of 1993 as in previous years (1991, 1992), groups with sizes of 28-34 cm, 40-50 cm and 54-60 have been identified from total sets of sizes. Two groups have largely consisted of non-pubescent individuals while the third one - of pubescent individuals.

Chum salmon, during feeding migration in the Bering Sea, belongs, as known, to many populations from different regions of its areal (Salo, 1991). In addition, in the first half of summer, both summer and autumn forms of chum salmon are found in the catches. With some share of conditional character, the individuals with maturity coefficient of more than 6 (on diagrams, two peaks were clearly seen) have been assigned to the summer race when operative analysis of the accounts data has been carried out. In the Bering Sea, among pubescent individuals, 4.8 thousands tons of 12.8 thousands tons while in the oceanic waters 5.1 thousands tons of 7.2 thousands tons fell to summer chum salmon.

An average length of pubescent chum salmon was 58.2 cm (2.6 kg) in the Bering Sea and 56.6 cm (2.5 kg) in the Pacific Ocean while one of non-pubescent chum salmon was 51.1 cm (1.6 kg) and 49.0 cm (1.5 kg) respectively, i.e. more large fish has been found in the more northern waters.

CONCLUSION

1. To a first approximation, the above redistribution in 1993 of Pacific salmons to the more northern waters can be, evidently, related to that in the Bering Sea as compared with

adjacent Pacific waters, the concentrations of macroplankton were higher. However, it should be born in mind that salmons migrate as the overwhelming bulk to the Komandor hollow and Kamchatka-Komandor region from the south-east and east rather than from the south. Hence, a northern trend in migrations must be formed even in spring when salmons were still further east and begun their movement from regions of winter habitation in the open ocean. Hence, it is most likely that this redistribution was a response of salmons on the reformation in oceanological conditions in the North Pacific on the whole.

It is well known that the deciding imprint is left on the forming the oceanological regime of the Bering Sea and adjacent Pacific waters by winter position of Aleutian atmospheric low. In the years when it takes up stationary position off the Kamchatka the Alaska Current weakens. In such situations, supply of oceanic waters to the Bering Sea through the Blizhny passage (separating the Komandorskie and Aleutian Islands) occurs from the south-west through the system of the West Subarctic Gyre. In the years when the Aleutian low shifts to the Alaska Peninsula, the Alaska Current strengthens under the action of prevailing winds. Correspondingly, with branches of this Current, a supply of oceanic waters to the Bering Sea, including through the Blizhny passage, increases. Such periods are considered to be warmer for the Bering Sea on the whole. From the beginning of 1990s, in the system of water circulation in the region under consideration, the tendency of development of oceanological processes according to the first scenario (Radchenko, 1993; Denman et al., 1991; Verkhunov, Tkachenko, 1992; Reed et al., 1993) has been determined as if according to the first scenario. In particular, in 1991, the Aleutian Current has been not almost traced off the western part of the Aleutian Islands. On the contrary, in the Blizhny passage, the northern branch of the Western Subtropical Gyre has been pronounced with subsequent confluence of it with the Kamchatka Current. The essential reformations in the structure of pelagic associations as well as in distribution of many marketable fishes are related to above changes in the water circulation (Radchenko, 1993; Shuntov et al., 1993). In the context of the foregoing, the year of 1993 was interesting in that, in this year, the Alaska Current was once again pronounced although it was not expected. It can be seen from Fig.2-4, that, in the vicinity of the Blizhny passage, one branch of this Current penetrated into the Bering Sea while the second branch, to the south of the Komandorskie Islands, has been traced to the southern direction. Thus, in the latter region, the water motion direction in 1993 was opposite as compared with 1990-1992.

In our opinion, such visible changes in the water circulation must imply considerable biotopic and even landscape reformations in the North Pacific and, undoubtedly, lead to corresponding changes in the composition and distribution of hydrobionts. For salmons, in this sense, a strengthening the Alaska Current was especially essential that must increase supply of oceanic waters into the Bering Sea through the passages of the

Aleutian Islands. This circumstance could provide more northern penetration of salmons even at initial stages of their spring migrations to the shores from open ocean, i.e. still before their coming to the waters off the Komandorskie Islands. In case of such situation, coming of most part of salmons to the Komandor hollow occurred not directly from the ocean but through southern part of the Bering Sea. Therefore, the possibility is provided to explain the distribution of pink salmon, chum salmon and fry of sockeye salmon shown in Fig.2-4.

2. If, when analyzing the general features of quantitative distribution of salmons, the fundamental dependencies on oceanological and hydrobiological conditions are well found then, in case of similar comparisons by individual species or age groups of salmons, the picture proved to be not as unambiguous. For example, the highest density of salmon concentrations by biomass has been found during survey to east of the Olyutorsky submarine ridge (Region 1 in Fig.1). However, biomass of macroplankton and squids were low in this region. Increased concentrations of pink salmon, chum salmon and fry of sockeye salmon in the Komandor hollow (Region 5 in Fig.1) correspond to quite high biomasses of macroplankton and squids. But the greater part of pubescent sockeye salmon was at the time concentrated to the south of the Komandorskie Islands (see Fig.4) where the lowest concentrations of macroplankton were found. True enough, here, a biomass of squid young was quite high (see Fig.1). Similar "discrepancies" in quantitative distribution of salmons and hydrobionts being their forage objects have been earlier found by us (Shuntov et al., 1993, 1993a). In this case, it was emphasized that for revealing the real ecological relations and regularities of quantitative distribution, in addition to considering the ecological specificity of each species of salmons, the information on the more fine structure of forage fields, vertical and horizontal aggregating groups of forage objects of fishes is needed. Data of total catches of plankton and nekton obtained in our expedition are, of course, inadequate.

3. The estimates of the quantity and biomass of salmons at final stages of marine periods of anadromous migrations made using trawling survey are of additional interest in connection with possibility of their comparison with data of coastal accounts (commercial catching and fish in the spawning-grounds).

Data of catching statistics and accounts in the spawning-grounds of chum salmon, sockeye salmon and coho salmon taking into account inhabiting in the Bering Sea and waters off the East Kamchatka of the two first species and representatives of groups from other regions including ones from the Sea of Okhotsk (Burgner, 1991; Salo, 1991) are well consistent with the quantitative estimates of these species in our expedition. One can also say that there were no any surprises in current season with respect to these species.

A situation with pink salmon of the East Kamchatka groups was different. Its take was almost 52 thousands tons. In addition, according to data of KamchatTINRO, about 30 thousands tons of pink salmon were accounted in the spawning-grounds. If a part of fish catch which is not accounted (poaching) and some ecosystem losses (seals, bears) are considered, then biomass of pink salmon in given region (82 thousands tons) should be considered as lower possible limit of its quantity during anadromous migrations. At the same time, during our survey, a biomass of pink salmon near the Kamchatka shores has been estimated at only 51.4 thousands tons (see Table 1). As can be judged from Fig.2, vanguard part of the pink salmon run was "cut off" from offshore. Therefore, incomplete account could only occur at the expense of fish remaining to the east of the survey area. It is truly, among the fish registered, only 41% fell on the female share. Based on the sex ratio close to 1:1, a total biomass of pink salmon was most likely not less than 63 thousands tons.

To the south of the Komandorskie Islands, in the Blizhny passage, all of the pink salmon came out essentially from the American zone. Here, already approximately 75% fell on the share of females. In the Bering Sea, a share of females was only 32% while at the boundary of economical zones, a sex ratio was close to 1:1. In this case. based on the arrangement of the pink salmon catches (Fig.2), one can with confidence assume that a zone with its increased concentrations has to some degree penetrated to the Bering Sea waters, off the Aleutian Islands. To be sure, that here during survey, at least a part of missing by sex ratio pink salmon has remained. However, with consideration for this quantity of fish, almost 20 thousands tons of "surplus" pink salmon were in the coastal accounts.

An inconsistency between marine and coastal estimates is evidently explained by two causes. It is possible that to the east of regions of our accounts, the quantity of pink salmon was somewhat higher than the estimate made on the basis of sex ratio. The more so, as the migration of part of fish to the more northern waters, namely, to the east and even north-east of the Olyutorsky Cape, is not ruled out. By the way, it is known from literature (Birman, 1985; Heard, 1991) that a quantity of pink salmon can come to the Karaginsky-Olyutorsky region, where its major spawning-grounds are located, from behind the Olyutorsky Cape.

It is not inconceivable that some quantity of pink salmon has been redistributed to the East Kamchatka spawning-grounds from other regions. We have already noted above that after completion of major run in July, pink salmon, judging from the catches, "moved up" to the region under consideration throughout whole August. A possibility of the pink salmon redistribution between regions follows from known hypothesis of fluctuating stocks (Glubokovsky, Zhivotovsky, 1986). In our opinion, a migration of a quantity of pink salmon was not in particular ruled out to the East Kamchatka region from the waters off the Kuril Islands. In this region, at the second stage of our expedition, the quantity of pink salmon registered was by several tens of thousands tons more as compared with the coastal registrations. More detailed discussion of this problem will be given in the following report.

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CAPTIONS TO FIGURES OF PAPER:

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Figure 1. Diagram of regions of the biostatistical information averaging (boundaries of regions are dotted lines, numbers are digits within squares).

Biomass of macroplankton within 0-50 m layer: 1 - less than 30; 2 - 30-50; 3 - more than 60 t/km; biomass of squids within 0-50 m layer: 4 - less than 0.1; 5 - 0.1-0.25; 6 - more than 0.25 t/km; biomass of salmons: 7 - less than 0.1; 8 - 0.1-0.3; 9 - more than 0.3 t/km.

Figure 2. Distribution of pink salmon catches in the western Bering Sea and Pacific waters off the Kamchatka, June 20-July 17, 1993: 1- 0; 2 - less than 10; 3 - 10-50; 4 - 50-100 specimens/hour of trawling. Solid lines are generalized diagram of currents; dotted lines are limits of males' share, %.

Figure 3. Distribution of chum salmon in the western Bering Sea and Pacific waters off the Kamchatka, June 20-July 17, 1993. Catches of non-pubescent chum salmon: 1 - 0; 2 - less than 5; 3 - 5-10; 4 - 10-20; 5 - more than 20 specimens/hour of trawling; 6 - major regions of the pubescent chum salmon accumulations. Solid lines are generalized diagram of currents.

Figure 4. Distribution of sockeye salmon in the western Bering Sea and Pacific waters off the Kamchatka, June 20-July 17, 1993. Catches of non-pubescent sockeye salmon: 1 - 0; 2 - less than 5; 3 - 5-10; 4 - 10-20; 5 - more than 20 specimens/hour of trawling; 6 - regions of the pubescent sockeye salmon occurence. Solid lines are generalized diagram of currents.

Table 1.

Biomass (thousands tons) of salmons in different regions of the Bering Sea and Pacific waters off the Kamchatka, June 20 - July 17, 1993

Regions	Pink	Chum		Sockeye		King	Coho	Dolly varden	All species (thousands tons)
		pubescent	nonpubescent	pubescent	nonpubescent				
1	5.46	4.68	9.43	0.05	2.33	0.63	-	5.30	0.55
2	0.04	-	-	-	-	0.17	-	-	0.21
3	-	-	-	-	-	0.25	-	-	0.25
4	0.09	0.06	-	-	-	-	-	1.51	1.66
5	32.02	8.03	17.85	0.05	8.77	1.54	0.26	4.53	73.50
In all 1-5	37.61	12.77	27.28	0.55	11.10	2.59	0.26	11.34	103.50
6	1.11	0.18	0.15	0.03	0.03	0.06	-	-	1.56
7	5.47	3.37	1.21	3.89	0.67	0.93	-	-	15.54
8	7.24	3.61	4.72	4.21	7.38	0.63	0.68	-	28.47
In all 6-8	13.82	7.16	6.08	8.13	8.08	1.62	0.68	-	45.57
In all 1-8 (1993)	51.43	19.93	33.36	8.68	19.18	4.21	0.94	11.34	149.07
In all (1991)	141.4		129.4		45.0	5.3	2.7	4.8	328.6

UDK 597.553.2 (265.53) Ichthyology

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Laboratory of Applied Biocenology,
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Abstract

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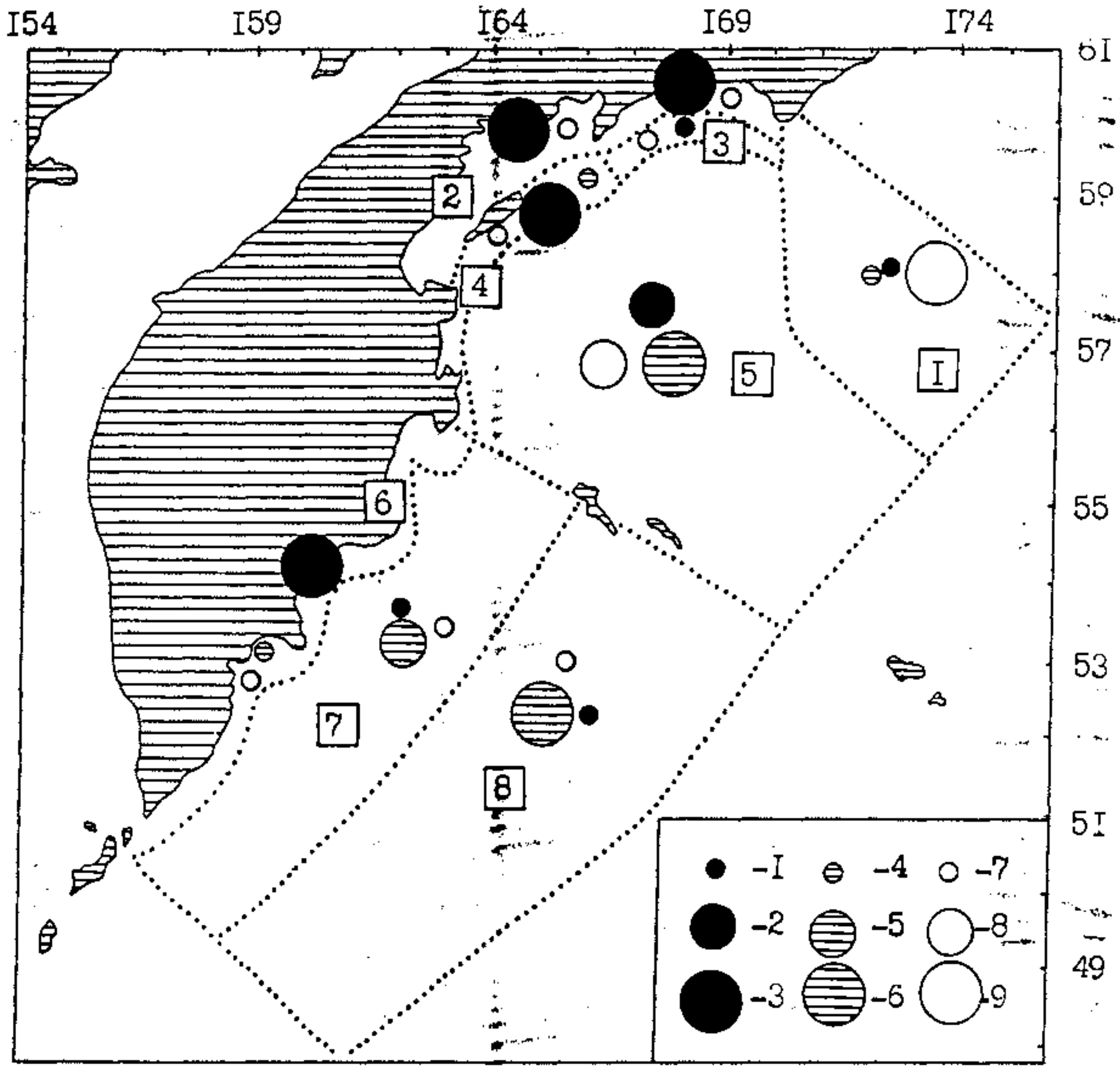

Fig. 1

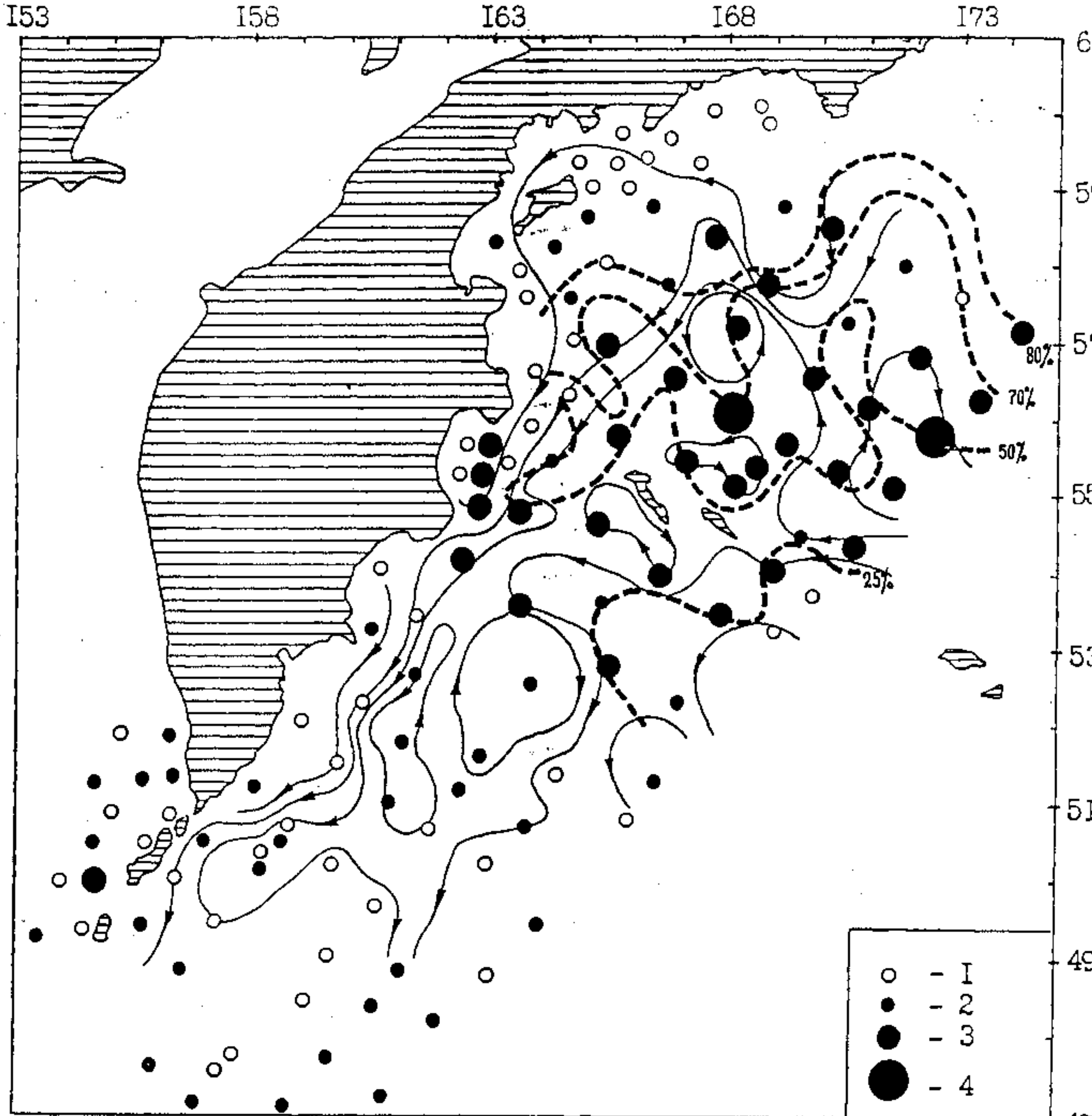

Fig. 2

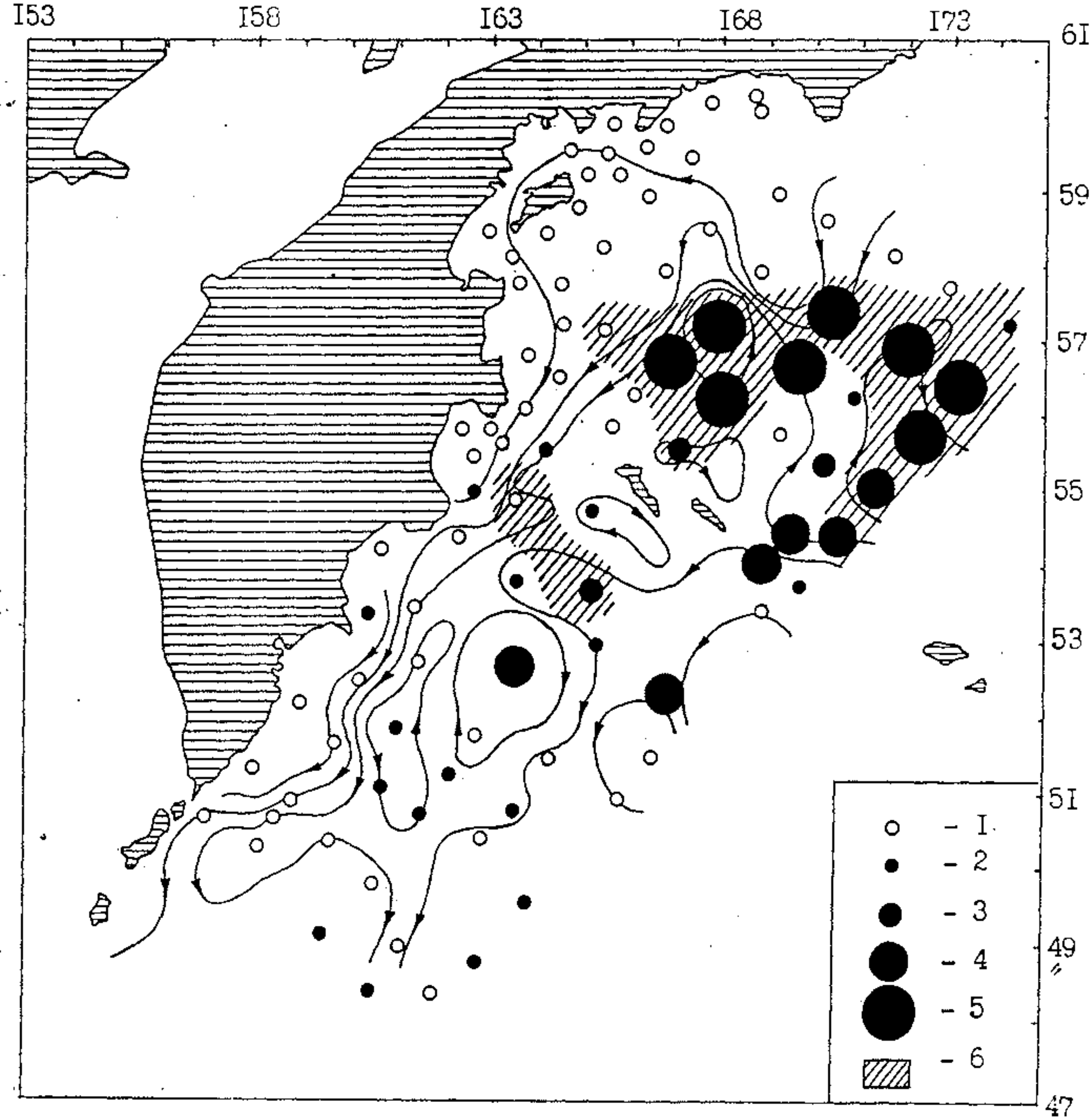

Fig 3

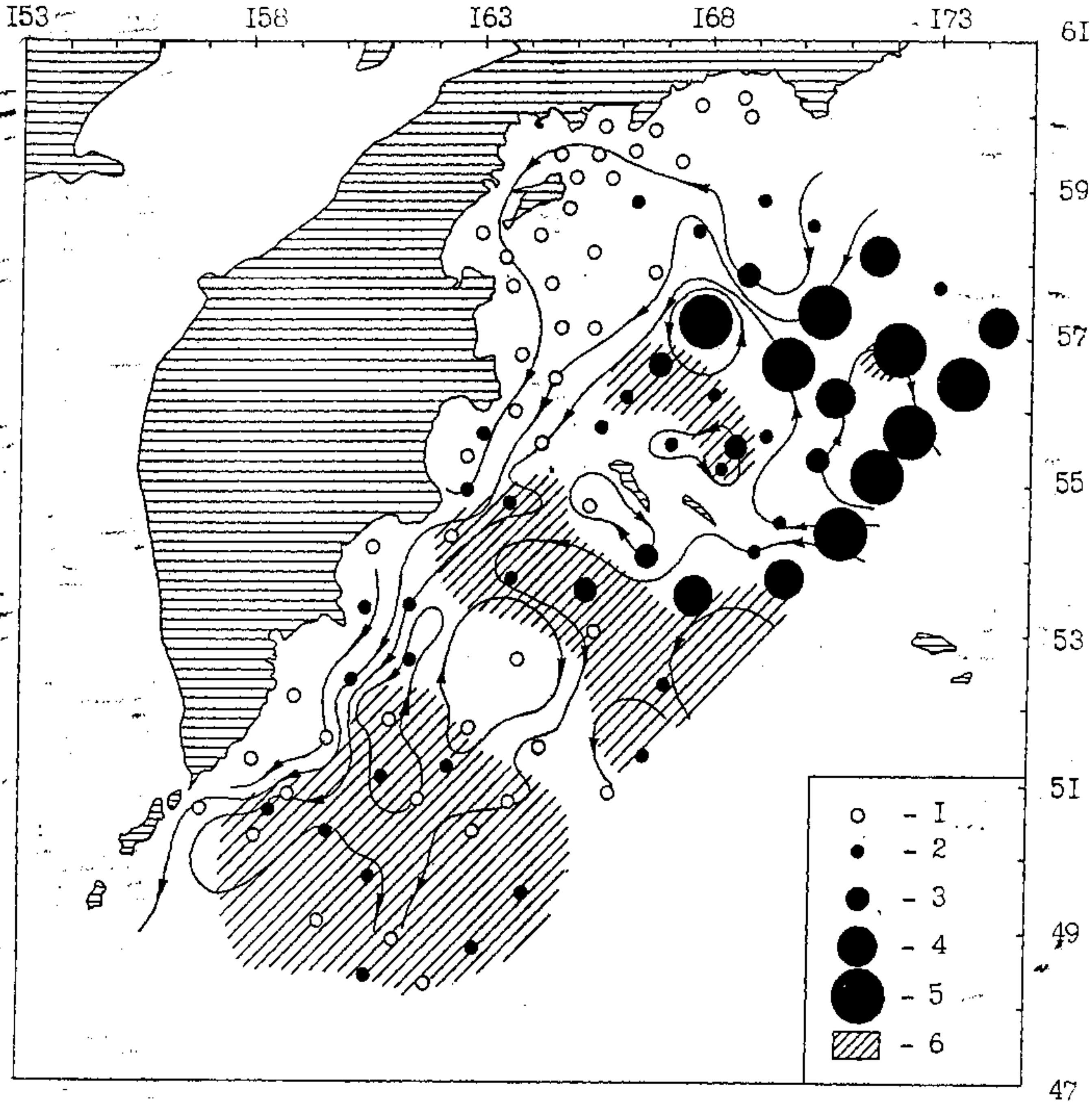

Fig 4