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Abstract

In order to clarify trophic relations and feeding habits juvenile salmon (Genus *Oncorhynchus*) and other major pelagic fishes, we examined the stomach contents of juvenile pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), masu salmon (*O. Masou*), sockeye salmon (*O. nerka*), chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), Atka mackerel (*Pleurogrammus monopterygius*), arabesque greenling (*P. azonus*) collected in the Okhotsk Sea and Pacific waters off the Kuril Islands during autumn of 1993. The major preny of pink, chum, and sockeye salmon were planktonic Amphipoda, *Themisto* sp. and *Primno* sp. Chum and pink also fed on a variety of inverbrates such as Gastropoda, Copepoda, Euphausiacea, and *Saggita* spp. Masu, Chinook, and coho salmon mainly fed on Cephalopoda and fishes. Prey species (diet niche) overlap was highest between pink and chum salmon, which were the most abundant species in this study. Prey species composition in their stomach contents is considered to reflect planktonic species composition in the environment. Inter-specific competition were lesser importance in the diets of pink and chum salmon.

Introduction

Pacific salmon (Genus *Oncorhynchus*) spend a certain period of time in fresh waters after hatching out in fresh waters. Thereafter most of them migrate to sea waters, which provide stable environment and food, and come back their natal rivers to spawn. The most specific ecological character of Pacific salmon is to achieve the rapid growth using high productivity of the ocean. Many studies on fresh water, estuarine, and the latter half of ocean (two year older) life of salmon were carried out. Especially, many scientists believed that high mortality in fresh and estuarine waters strongly affect the strength of the year class of salmon and focused their efforts on ecology of their life spans (Parker 1968, 1971; Mathews and Buckley 1976; Bax 1983; Furnell and Brett 1986; Fisher and Pearcy 1988). On the other hand, much information on the latter half of ocean life is accumulated in order to carry out the fishing management (Manzer et al. 1965; Tanaka et al. 1969; Neave et al. 1976). Recently, the carrying capacity of salmon in the North Pacific Ocean are being discussed internationally. It is considered that juvenile salmon migrate from near coast waters towards offshore waters after autumn. Rapid environmental changes may strongly affect their growth and survival there. However, there is few of information on juvenile salmon in this season, because seasonal rough weather had obstructed the research activities in offshore waters.

Fisheries Agency of Japan conducted the research cruise to elucidate distribution and migration routes of the juvenile salmon in the Okhotsk Sea and the Pacific waters off the Kuril Islands in the autumn of 1993. The results of this research showed that juvenile salmon and greenling (*Pleurogrammus* spp.) dominated in the surface layers of the survey waters. We examined the stomach contents of them in order to clarify their feeding habits. Relating spatial distribution of them with the degree of prey species overlap found in their stomach, we tried to estimate the basic trophic relation among juvenile salmon and greenling. Moreover, environmental factors that may affect survival and distribution of juvenile salmon during their autumn-winter offshore migration were discussed based on the trophic relation of them with oceanographic information.

Materials and methods

Survey areas and periods

The sampling operations were conducted in the Okhotsk Sea and Pacific waters off the Kuril Islands of the south of 50° N from October 12 to November 30, 1993 using the Research Vessel *(R/V) Kaiyo-maru* (2,630GRT; Fig. 1). The sampling transects were situated to cross the chain of at right angle to. Five transects with 20 sampling stations were located in the Okhotsk Sea and 4 transects with 11 sampling stations in the Pacific waters off the Kuril Islands. All sampling stations were surveyed once in the first (from October 12 to November 2: October research) and latter (from November 9 to November 30: November research) half of the research period respectively.

Oceanographic observation

CTD observations (from the surface to 1,500m deep layer) were carried out at each sampling station just before or after the sampling operation in order to investigate the physical oceanographic structures of the sampling area. We mainly examined the distributions of temperature and salinity at the sea surface and the 50 m deep layer, because the most of salmon are considered to be only distributed within the near surface layers of the surface to the 50 m (Machidori, 1966; Straty, 1974, Ogura, 1993).

Sampling gear and collection of juvenile samples

The mid-water trawl was used to collect juvenile salmon. The sizes of the trawl were 50m in height and 60m in width at the mouth of the net. Mesh size at the cod-end of the trawl was 12mm. Towing velocity of the trawl was about 280cm/sec (5.5 knot) and towing time was 60 minutes per operation. Because all of trawl operations were conducted at surface for 60 minutes towing at 5 knot, we can regard CPUE as the catch number directly. The trawl was operated always to cover the layers from the surface to the depth of 50m. Sampling operation were mainly conducted at daytime.

Biological measurements and methodology for analyses

Juvenile salmons (*Oncorhynchus* spp.) and grennlings (*Pleurogrammus* spp.) collected by the mid-water trawl were identified into species and measured in length and body weight onboard. After that, they were immediately frozen at −40℃ and carried to a laboratory to analyze their stomach contents. We randomly took the whole stomachs of 20 individuals every sampling station by species and preserved them in 10% formalin solution. Stomach contents were observed with the naked eye or the microscope. Prey organisms found in their stomachs were identified into species so far as it is possible. Wet weights were measured by biological category and stomach content index (SCI; wet weight (g)/ body weight of the fish (g) x 100) were calculated. Frequency of occurrence and percentage of wet weight were calculated by species. In order to estimate the degree of inter-specific competition in the feeding, the percent similarity indices (PSI) among species were calculated and the cluster analysis was done based on PSI using the grouped average method (Whittaker, 1994; Tanaka et al., 1984). PSI is given with the following formula.

$$PSI=1.0-0.5S|P_{ij}-P_{hj}|$$

Where are

P_{ij} : percent of wet weight of biological category j of species i.

P_{hj}: percent of wet weight of biological category j of species h.

Results

Oceanographic condition

Temperature distributions at the sea surface and the 50 m layer in the survey area are shown in Fig2-a. Surface sea temperatures (SST) ranged from 5 to 11 °C in the Okhotsk Sea and from 4 to°C in the Pacific waters off the Kuril Islands in October. SST distribution shows that cold waters, originating in the Oyashio, were distributed in coastal waters off the northern Kuril Islands and warm waters, originating in the Soya Warm Current, extended from the southern Okhotsk to the central Okhotsk. At the 50m layer, warm waters occurred only in the south-eastern Okhotsk and cold waters (3°C>) were widely distributed in the other areas of the Okhotsk Sea.

In November, SST generally declined about 2-4°C to 3-9°C in the Okhotsk Sea and to 3-5°C in the Pacific Ocean. At a part of the Okhotsk Sea, where warm waters were distributed in October, SST drastically decreased. At the 50m layer, cold waters (3-5°C) spread all the survey areas except for south-eastern Okhotks Sea, where warm waters remained.

Salinity distributions at the 10m and 50m layers are shown in Fig. 2-b. In October, it is distinctive that high salinity waters (33.0 psu <) were distributed from the southern Okhotsk to the Pacific waters off the southern Kuril Islands. Low salinity waters (33.0 psu >) widely spread over the central Okhotsk Sea and the Pacific waters off the northern Kuril Islands. In November, salinities at the both layers were increased throughout the research areas. The salinity distribution in the research areas was not change so much from October to November.

Distribution of water temperatures and salinities suggests that warm and high salinity waters originating in the Soya Warm Current were distributed in the southern Okhotsk Sea and the Pacific waters off the southern Kuril Islands. It also revealed that cold and low salinity waters spread over the central Okhotsk Sea and coastal waters off the northern Kuril Islands.

Appearance and distribution of pelagic organisms

Pink salmon (*Oncorhynchus gorbuscha*) was most abundant species in the catches, and followed by chum salmon (*O. keta*; Figs. 3 and 4). Juvenile (0.1) chum and pink salmon were distributed only in the Okhotsk Sea in Ocotber. In November, they occurred in the Pacific waters off the northern Kuril Islands. Total bio-mass of these two salmons occupied 74% of the whole total bio-mass. Other four species of salmons, sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chinoodk salmon (*O. tshawytscha*), and masu salmon (*O. masou*) were also often collected (3.0% of the total bio-mass). Except for salmon, arabesque greenling (*Pleurogrammus azonus*) and atka mackerel (*Pleurogrammus monopterygius*) were comparatively abundant (about 8.0% of the total bio-mass, Figs. 5 and 6). More than 90% of salmon and 99% of greenling collected belonged to juvenile stage (ocean age 0) and their body lengths were ranging from 150mm to 300mm. We analyzed the stomach contents of only juveniles of the above eight species for examining the trophic relation of pelagic organisms, because they occupied 85% of the total catch and seemed to belong to the same or near trophic stages.

Gonate squids (for example, boreopacific gonate squid, *Gonatopsis borealis*), lantern fishes (for example, *Tarletonbeania taylori*), and deepsea smelts (for example, northern smooth-tongue, *Leuroglossus schmidti*) were also often caught. The most part of them were less than 100mm in body length. Accordingly, the their trophic level were considered to be different from those of the previous eight species. In total, twenty eight species of pelagic organisms were collected (including 5 unidentified species).

Distribution of juvenile pink and chum salmon: Catch distribution of pink salmon were shown in Fig. 3. The most part of them belonged to juvenile stage (0.0). Juvenile pink salmon were found at all sampling stations in the southern and central Okhotsk Sea in October. Their distribution seemed to spread more northern areas of the Okhotsk Sea, where the sampling operations were not done. SST and salinity ranges at juvenile pink salmon distribution were from 5.1℃ to 12.1℃ and from 32.1psu to 33.2psu. Juvenile pink salmon were abundant at SSTs of 6-8℃. In the Pacific Ocean, a few of pink salmon was found only in coastal waters off the mid-Kuril Islands. In November, juvenile pink salmon disappeared from the central Okhotsk Sea, where SST decreased in less than 5℃. They occurred in the southern Okhotsk and the Pacific coast off the mid-Kuirl Islands. Their distribution was found at SST ranging from 2.8℃ to 9.0℃ and Salinity from 32.1psu to 33.5psu.

Catch distribution of chum salmon were shown in Fig. 4. More than 95% of chum salmon belonged to juvenile stage (0.0). The distribution pattern of juvenile chum was very similar to those of juvenile pink salmon distribution. In October, juvenile chum were widely distributed in the southern and central Okhotsk Sea. In the Pacific waters, very few juvenile chum salmon occurred only in coastal waters off the mid-Kuril Islands. In November, they disappeared from the central Okhotsk Sea and occurred in the southern Okhotsk Sea and the Pacific waters off the mid-Kuril Islands. Their distribution pattern was the same as the distribution pattern of juvenile pink salmon.

Juvenile chum salmon were collected at the same twenty sampling sites in October as juvenile pink salmon collected and collected at the same fifteen sampling sites in November. This suggests that juvenile pink and chum salmon were inhabiting together or their distribution overlapped each other seriously.

Distribution of other salmon: The most part of other salmon also belonged to juvenile stage (X.0). Juvenile masu salmon were collected at 10 sampling stations in October and at 8 sampling stations in November. Numbers of collected per sampling station were ranging from 1 to 8. A few juvenile sockeye salmon were caught at 5 sampling stations in October and at 3 sampling stations in November. They were found in the Okhotsk coast waters off the northern and central Kuril Islands. Juvenile coho salmon were collected at 10 sampling stations in October and 2 sampling stations in November. Numbers of collected per sampling station were ranging from 1 to 14. Juvenile chinook salmon were collected at 2 sampling stations in October and at 5 sampling stations in November. Number of collected per the sampling station were ranging from 1 to 14.

Distribution of major non-salmon species: Catch distribution of Atka mackerel were shown in Fig. 5. They were collected at 5 sampling stations in October and 3 sampling stations in November in coastal waters off the central and northern Kuril Islands. Catch distribution of arabesque greenling was shown in Fig. 6. They were very abundant in the southern Okhotsk Sea in October and very few in November throughout the survey areas. SST range of their distribution were from 6.8℃ to 11.6℃ and higher than that of distribution of Atka mackerel. Distributions of Atka mackerel and arabesque greenling hardly overlapped.

Fork length frequencies

We show body length frequencies of juveniles of pink salmon (fork length (FL): n=637), chum salmon (FL: n=424), masu salmon (FL: n=25), sockeye salmon (FL: n=33), chinook salmon (FL: n=17), coho salmon (FL: n=14), arabesque greenling (standard length (SD): n=47), and Atka mackerel (SD: n=95) in Fig. 7. Fork lengths of juvenile pink salmon were ranging 180 mm to 340 mm with a mode of 240mm, and juvenile chum salmon from 160mm to 300mm with a mode of 230mm. Fork length frequencies of both species were obviously mono-modal. Fork lengths dispersion of other salmon were more scattered than pink and chum salmon. However, masu salmon, coho salmon, and chinook salmon were obviously larger than pink and chum salmon in fork length.

Feeding habits

Pink and chum salmon: Percentages in wet weight and occurrence frequency in stomach content by the prey category for pink salmon were shown in Table 1. We found some identifiable stomach contents in 553 individuals in the stomachs of 637 pink salmon. Twenty two biological categories were identified in their stomachs. Planktonic amphipods (*Themisto* spp., and *Primono* spp.), *Sagitta* spp., and planktonic gastropods often occurred in their stomachs. Especially, *Themisto* spp. were found in 86 % of the whole identifiable stomachs and *Primono* sp. in 70%. Although occurrence frequencies of copepods and Euphausiacea larvaes were comparatively high, percentages of their wet weight in the whole stomach content weight were very low. In contrast to these species, percentages of the wet weight of *Themisto* spp. and *Primno* spp. were very high (41% and 17%). The above two species are considered to be the most important preys for pink salmon. Added the weights of *sagitta* spp., and plnaktonic Euphausiacea to the weights of the above two species, the total weights reached more than 80% of the whole stomach content weight. Pink salmon also utilized various organisms, such as megalopas, fish larvae, squids, and terrestrial insects, as their prey organisms.

Percentages in wet weights and occurrence frequency in the stomach contents by the prey category for chum salmon were shown in Table 2. We found some identifiable stomach contents in

398 individuals in the stomachs of 424 pink salmon. Twenty one biological categories were identified in their stomachs. The composition of prey organisms of chum salmon was very similar to that of pink salmon. The occurrence frequencies of *Themisto* spp., and *Primono* spp. in the whole identifiable stomachs were very high (91 and 73%). Percentages of their wet weight in the whole stomach content weight also were very high (30% and 21%) . Accordingly, the above two species were the most important preys for chum salmon as well as for pink salmon. Percentage of occurrence frequencies of gastropoda in the non-empty stomachs of chum salmon was low and that of *sagitta* spp. was high compared with those of pink salmon. Added the weights of *sagitta* spp., and plnaktonic Euphausiacea to the weights of *Themisto* spp., and *Primono* spp., the total weights reached more than 90% of the whole stomach content weight.

Other salmon: Percentages in wet weight and occurrence frequencies by the prey category for masu salmon were shown in Table 3. We found some identifiable stomach contents in 19 individuals in the stomachs of 20 individuals. Seven biological categories were identified in their stomachs. The occurrence frequencies of *Temisto* sp. and *Euphausia pacifica* were comparatively high, however, as for percentage of the wet weight, fishes occupied a large part in the whole (95%). In the fishes, Japanese anchovy (*Engraulis japonica*), northern smooth-tongue (*Leurogrossus schmidti*) and lanternfishes (Myctophidae) were major species.

Percentages of wet weight and occurrence frequencies by the prey category for sockeye salmon were shown in Table 4. Prey species composition in the stomach contents of sockeye salmon is similar to that of pink and chum salmon. *Themisto* sp., *Primono* sp., and *Sagitta* sp. were found very frequently in their stomachs. Especially, percentage of *Sagitta* sp., and *Themisto* sp. was very high in the wet weight composition (Fig. 8). Accordingly, these two species are considered to be the most important preys for sockeye salmon.

Sample sizes of chinook and coho salmon were very samll (17 and 14 individuals). Squids were considered to be major preys for them in the both sides of wet weight composition and occurrence frequency (Tables 5 and 6, and Fig. 8).

Major non-salmon species: Percentages in wet weight and occurrence frequencies by prey category for Atka mackerel and arabesque greenling were shown in Tables 7 and 8. Prey species composition in the stomach contents of Atka mackerel was comparatively similar to those of pink, chum, and sockeye salmons. However, Copepoda (65%) and fishes (39%) were more frequently found in their stomachs as compared with these salmons. *Sagitta* sp. was an important prey in wet weight for Atka mackerel as well as for sockeye salmon.

Occurrence frequencies of *Themisto* sp. and *Sagitta* sp. in the stomachs of arabesque greenling were very high (65% and 85%). Because a small part of specimens of arabesque greenling ate a large quantity of Gastropoda, percentage of Gastropoda in wet weight seems to be high (37%). However, Occurrence frequency of Gastropoda was very low (2%). Accordingly, we consider that *Themisto* sp., and *Sagitta*. sp. were major prey species for Atka mackerel and arabesque greenling.

Geographical distribution of Stomach Contents Index (SCI) of pink and chum salmon

The averages and standard deviations of SCI of pink and chum salmon at each station, where more than 10 individuals were examined for their stomach contents, are shown in Fig 9 and 10. These figures indicate that the dispersions of SCIs are very large. The average SCIs also seems to vary widely and randomly by station. The differences in SCIs between the samples collected in the Okhotsk Sea and in the North Pacific were unclear.

Relationship between Cacth per Unit Effort (CPUE) and SCI

We examined the relationship between catch per unit effort (CPUE) and SCI for pink and chum salmon (Figs. 11 and 12). These figures suggests that there are no clear positive or negative correlation between CPUE and SCI, and density-dependent effect on their feeding activities is also unclear. However, for pink salmon, the stations where CPUEs were very high (more than 1,000) accorded with the stations where SCIs were very low (less than 10). This suggests that there may be insignificant density-dependent effect on feeding activity of pink salmon.

Relationship between CPUEs of pink and chum salmon

As noted previously, juvenile pink and chum salmon were collected simultaneously at the many sampling stations in October and November. We examined the relationship between CPUE of both species at 42 sampling stations, where either of both species is collected (Fig. 13). This indicates that there is significant positive correlation between them ($r=0.350$, $P<0.05$).

Relationship between SCIs of pink and chum salmon

We also examined the relationship between average SCIs of pink and chum salmon at each sampling station, where more than 10 individuals of both species were collected (Fig. 14). We could not find clear correlation between them, however, the station where SCIs of pink salmon were high accorded with at the stations where average SCIs of chum salmon were also high. This may suggest that intra-specific competition for prey organisms between pink and chum salmon was not so hard.

PSI of major species and trophic relations among them

To estimate degrees of the similarity and overlap in prey species among eight major pelagic species, PSI among the species were calculated and a dendrogram was made from the cluster analysis (the grouped average method) based on PSI (Table 9, Fig. 15). PSIs were significant (>0.6) in the nine combinations (Table 9). PSI (0.86) of the combination of pink and chum salmon is highest in them. The combinations of both the two species and the following three species, sockeye, Atka mackerel, and arabesque greenling are also comparatively high in PSI (0.52-0.75).

The dendrogram (Fig. 15) shows that three clusters are formed at PSI-0.5. Pink, chum, and sockeye salmon, Atka mackerel, and arabesque greenling formed a cluster (Cluster A). On the other hand, coho and chinook salmon formed a cluster (Cluster B). Masu salmon were independent of these clusters (Cluster C). Considering the results of the cluster analysis in combination with the stomach contents examination (Table 1-8), we can suggest that the species of Cluster A (pink, chum, and sockeye salmon, Atka mackerel, and arabesque greenling) are classified into the plankton feeder and the species of Cluster B (coho and chinook salmon) into the squid predator. Masu salmon of Cluster C can be classified to be the fish predator in a similar consideration. This dendrogram also indicates that the similarity in feeding habits between pink and chum salmon is very high.

Discussion

The Okhotsk Sea is characterized by the Okhotsk Sea intermediate cold water originating in a great amount of sea ice, which is formed in the long cold winter (Ogata, 1976). The coastal Oyashio Current , a part of which is also originating in sea ice, flows southwards in the vicinity of the Kuril Islands (Otani, 1989). The western Kamchatka Current runs northwards along the western coast of the Kamchatka Peninsula and the Sakhalin Current flows southwards along the eastern coast of Sakhalin (Hanawa, 1984). The Soya Warm Current, which is originating in the Tsushima Warm Current, warm and high salinity, flows eastwards along the Okhotsk coast of Hokkaido. The Soya Warm Current passes the straits of the southern Kuril Islands and flow out from the Okhotsk Sea into the North Pacific Ocean (Kurashina, 1967; Hanawa, 1984).

Juvenile pink and chum salmon were distributed in waters north of the Soya Warm Current in October (SST 5.1-12.1℃, salinity at surface 32.13-33.18 psu). In November, SSTs in their distribution area were ranging from 2.8℃ to 9.0 ℃ and salinity at surface ranging from 32.06 psu to 33.54 psu, respectively. Pink and chum salmon fry are believed to be distributed in waters ranging from 8℃ to 14℃ in SST and from 31.0 psu to 33.9 psu in salinity at surface (Chupakin and Kaev, 1980; Irie; 1990). On the other hand, Manzer et al. (1965) noted that distribution of mature and immature chum salmon are found from 1℃ to 15℃ in SST and their preferred range of SST is from 3℃ to 11℃. Accordingly, the results of this study may suggest that SST range of distribution of juvenile pink and chum salmon collected in this survey are close to that of mature and immature salmon rather than that of the fry.

Juvenile pink and chum salmon were collected together at 20 sampling stations in October and 15 sampling stations in November. There is significant positive correlation between CPUEs of juvenile pink and chum salmon. These indicate that juvenile pink and chum salmon have a same preference to the environmental factors and their habitat niches overlap. These also indirectly suggest that the carrying capacity for juvenile salmon did not become saturated. Neave (1966 a and b) reported that inhabiting place of juvenile pink and chum salmon often overlaps in coastal waters off the Pacific coasts of North America. Accordingly, we consider that habitat overlaps of juvenile pink and chum salmon are general phenomenon.

We found a variety of planktonic organisms (for example, Amphipoda, Euphausiacea, *sagitta* sp., megalopa, fish larvae, squid, and terrestrial insects) in the stomach contents of pink and chum salmon. The most important prey for juvenile pink and chum salmon was Amphipoda (Fig. 8). Especially, *Themiso* sp., and *Primono* sp. in Amphipods were important (Table 1 and 2). There is few information on *Primono* sp as the prey for salmon and *Themisto* sp. are very common prey species for salmon and other fishes in the sub-arctic regions of the North Pacific Ocean (Sugizaki, 1988; Takeuchi, 1972). The result of this study also suggests that *Themisto* sp., is an important prey species for juvenile sockeye salmon, Atka mackerel, and arabesque greenling. Brodeur and Pearcy (1990) examined stomach contents of juvenile salmon in the summers of four years and concluded that prey species composition in the stomach of salmon depended on composition of planktonic organisms in the environment. Kaczynski et al., (1973) investigated geographical variation of stomach contents of juvenile salmon. They found that there was few variation in prey species composition among juvenile samples collected within the same sea area and there was large variation among juvenile samples collected among the different sea areas. Based on the above two information, we consider that the predominant prey species (*Themisto* sp. and *Primono* sp.) for juvenile salmon in this study also reflected species composition of zooplankton in the environment rather than preference of juvenile salmon.

Brodeur and Pearcy (1990) reported that juvenile chum and sockeye salmon have the preference for zoopkankton in feeding and juvenile coho and chinook salmon have the preference for fishes. This study also shows juvenile pink, chum and sockeye salmon have preference for zooplankton and juvenile coho, chinook, and masu salmon have preference for fishes or squids. These suggests the feeding habits of juvenile salmon collected in this study is close to those of mature and immature salmon, of which feeding habits were reported by Ito (1964), Kanno and Hamai (1971), Kitano (1984).

It is reported that bio-mass of Copepoda was larger than that of Amphipoda in summer in the Okhotsk Sea (Shuntov et al., 1988, 1990, and 1993) and juvenile pink and chum salmon utilized Copepoda as their main prey (Kun, 1986). On the other hand, the stomach content analysis in this study shows that Copepoda was not important prey for juvenile salmon collected in this study. Copepoda moves downward to deep layers from summer to winter, accompanied by decrease in bio-mass of phytoplankton at the surface layer (Fulton, 1973). We consider that this downward vertical migration of Copepoda may decrease chance for juvenile salmon to eat Copepoda at surface layers.

As noted previously, although the habitat of pink and chum salmon overlapped seriously, the similarity in the prey species composition of both species was very high. This suggests there are intra-specific competition in feeding between both species potentially. However, Broudeur and Pearcy (1992) reported that increase of abundance of food make predators concentrate in some specific food and the similarity in prey species composition among competitors also increase. Based on the above consideration and information, because we observed high similarity in prey species composition between pink and chum salmon, it may suggest that the bio-mass of preys were abundant in the survey areas.

Considering that (1) density-dependent decrease of SCI was unclear (Figs. 11 and 12), (2) the average SCIs also seems to vary widely and randomly by station (Figs. 9 and 10), we concluded that abundance of prey organisms in the survey area did not act as a main factor to regulate the migration and distribution of juvenile salmon. Moreover, we supposed that negative correlation in SCI among species could be recognized if there is exclusive competition in feeding. However, the result of this study indicates that exclusive competition in feeding is not serious, because significant negative correlation in SCI between these species were not recognized (Fig. 14).

On the other hand, as for pink salmon, there may be insignificant density-dependent decrease of SCI (Fig. 11). This suggests that abundance of prey organisms is not always sufficient for juvenile salmon. Accordingly, we should examine relationship between prey abundance in the environment and stomach contents of juvenile salmon in other year in order to confirm existence of density-dependent effect on feeding and inter- and intra- specific competition on feeding activity.

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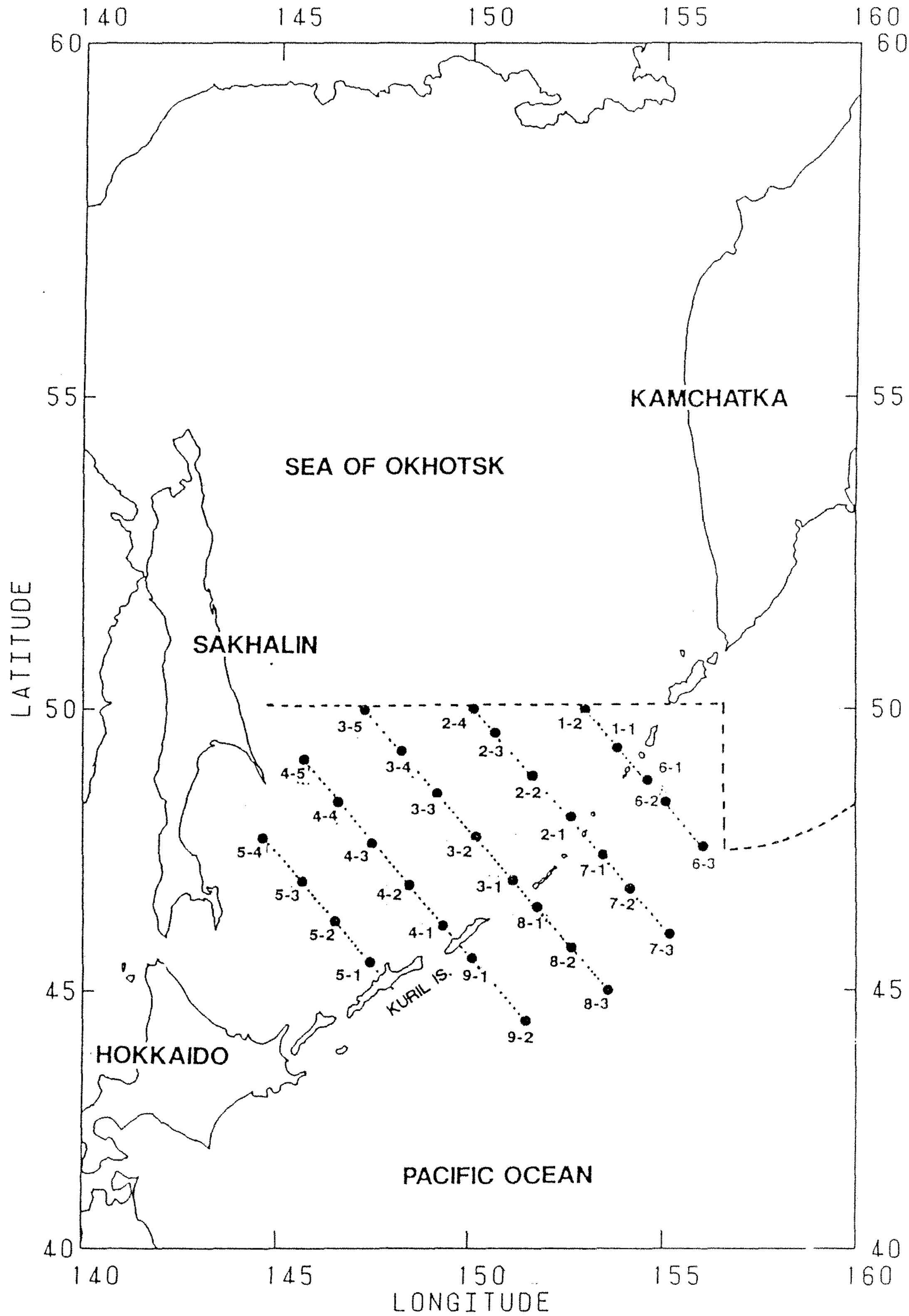


Fig. 1. Charts showing sampling transects and stations.

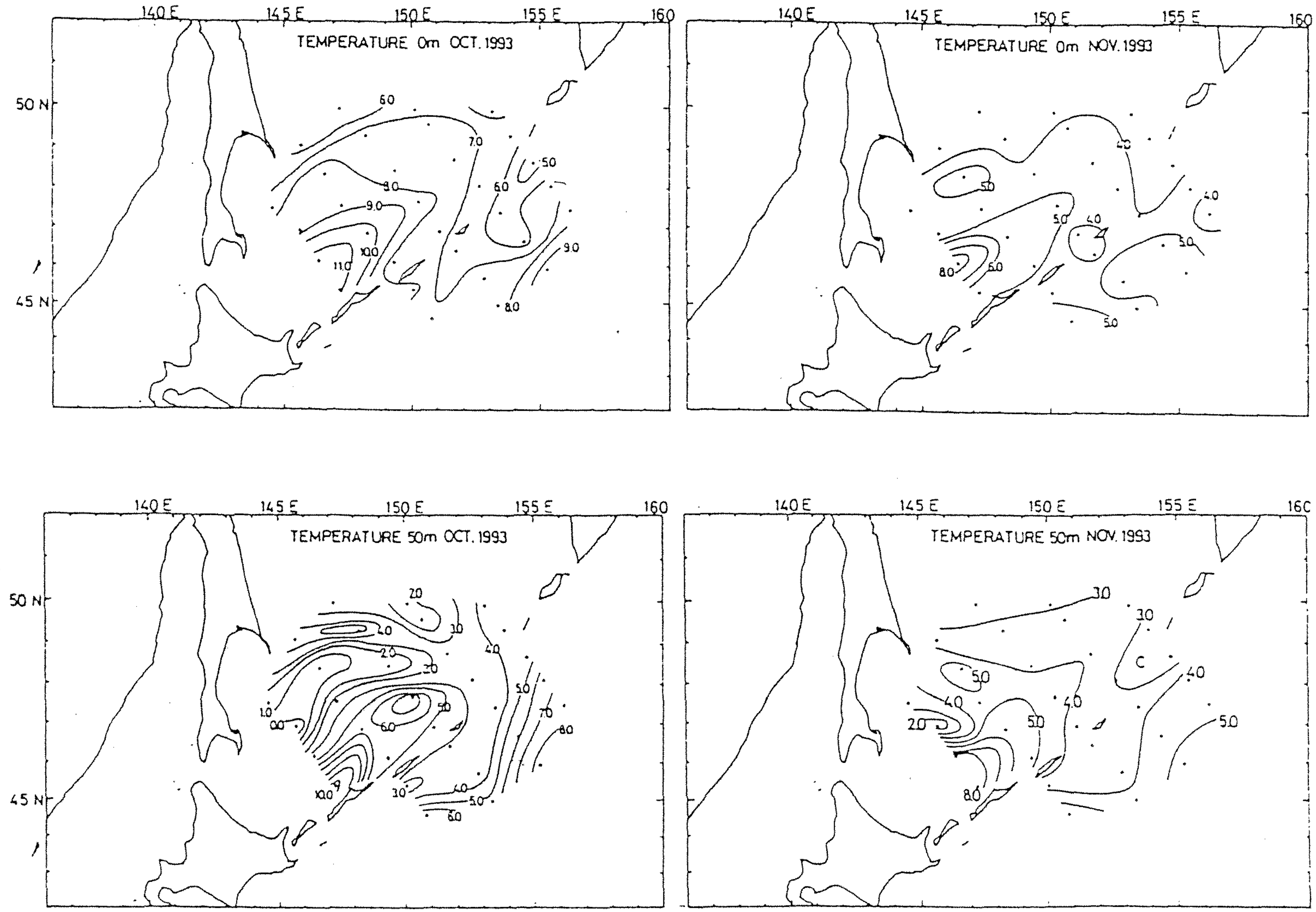


Fig. 2-a. Charts showing distribution of isotherms at the surface (upper) and 50m deep (bottom) of the study area during the research cruise, October (left) and November (right), 1993.

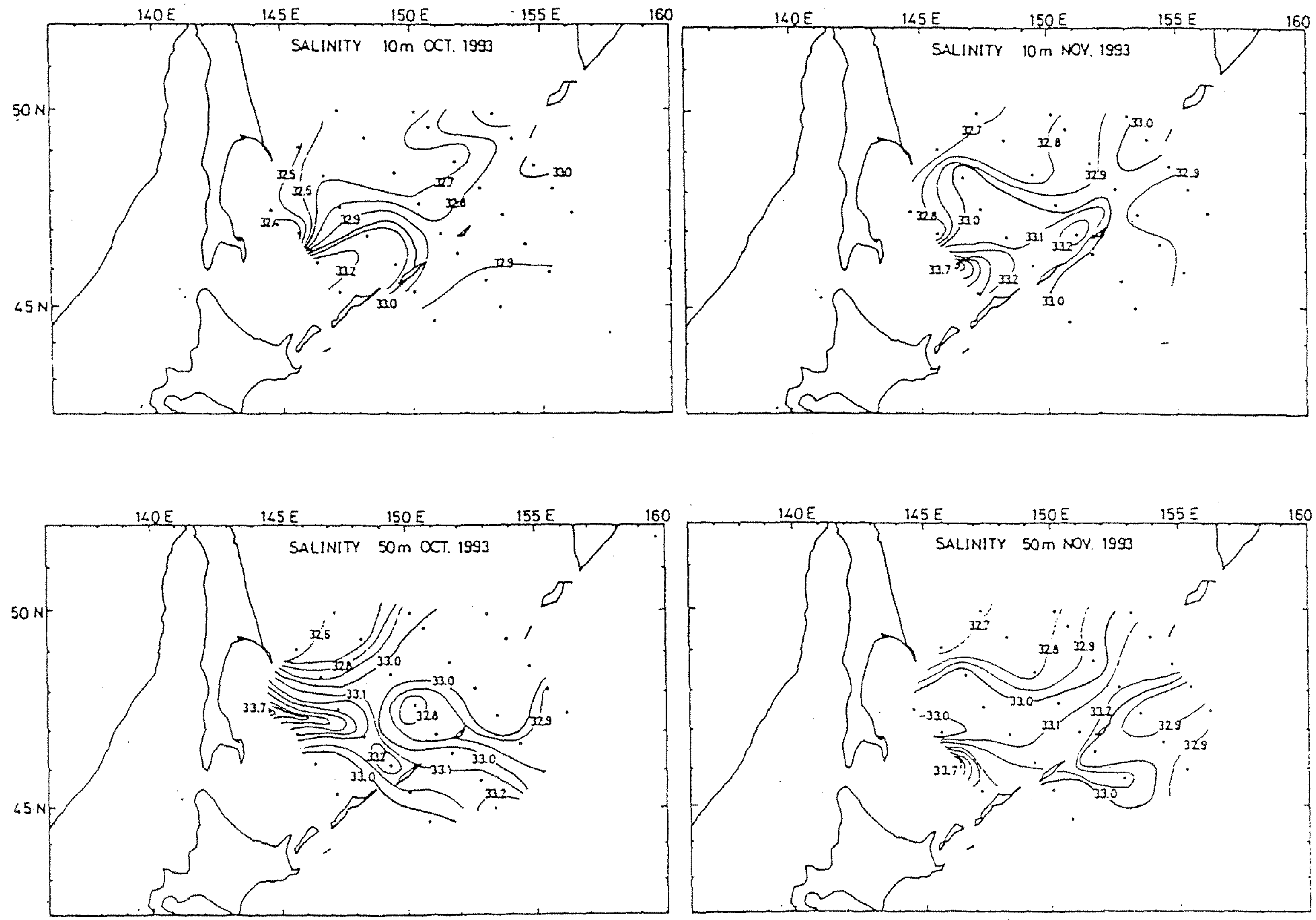
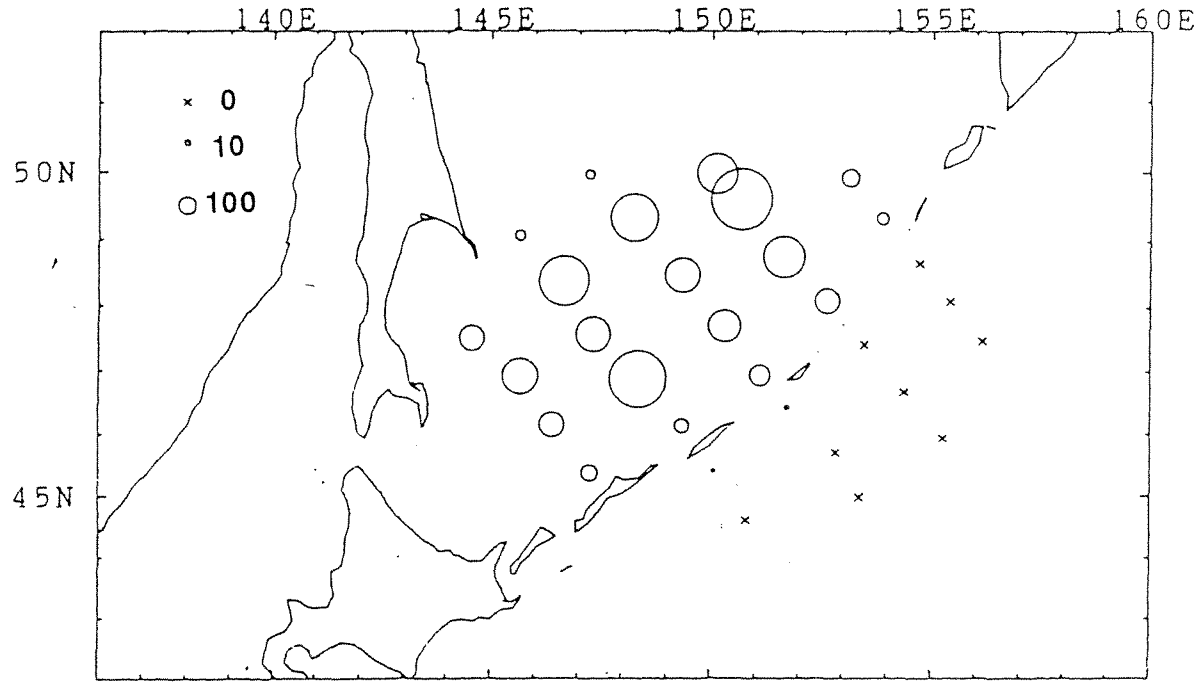


Fig. 2-b. Charts showing distribution of isohalines at 10m deep (upper) and 50m deep (bottom) of the study area during the research cruise, October (left) andNovember (right), 1993.



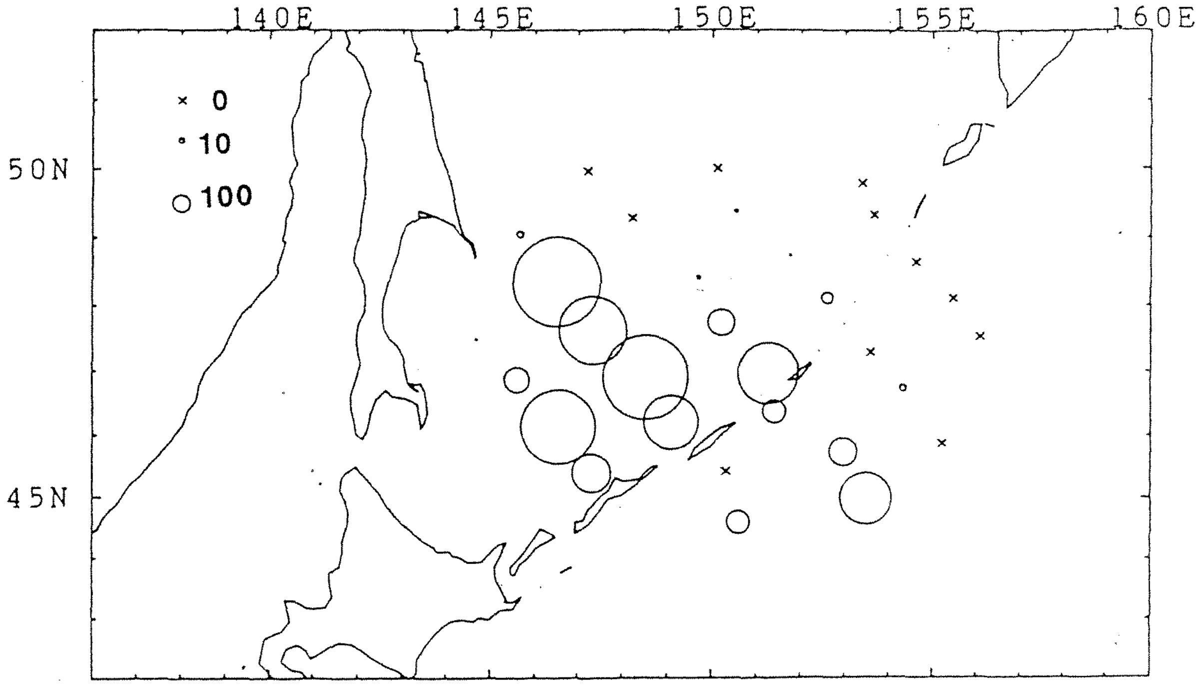


Fig. 3. Charts showing CPUE of pink salmon during October (upper) and November (bottom), 1993.

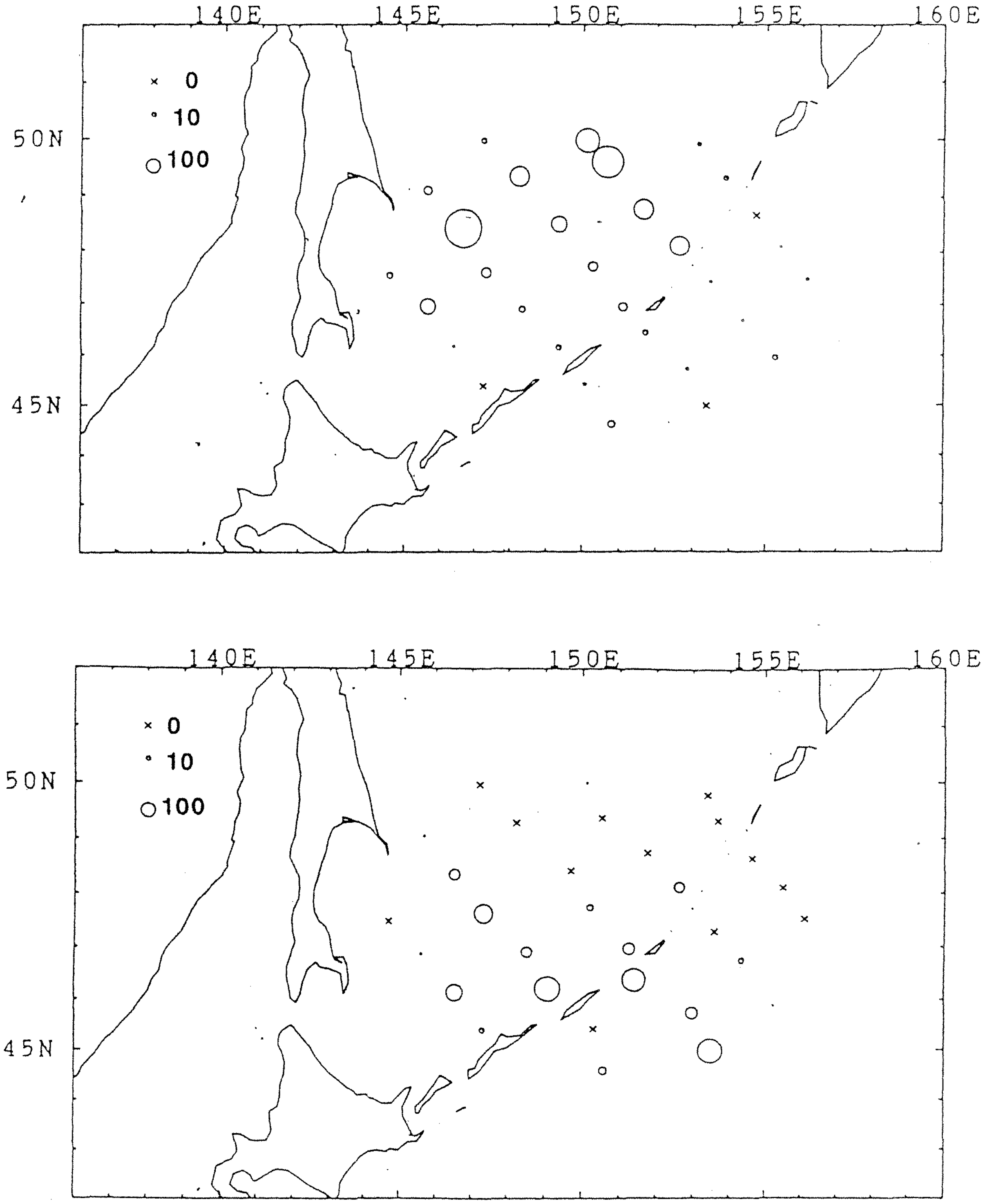


Fig. 4. Cahrts showing COUE of chum salmon during October (upper) and November (bottom), 1993.

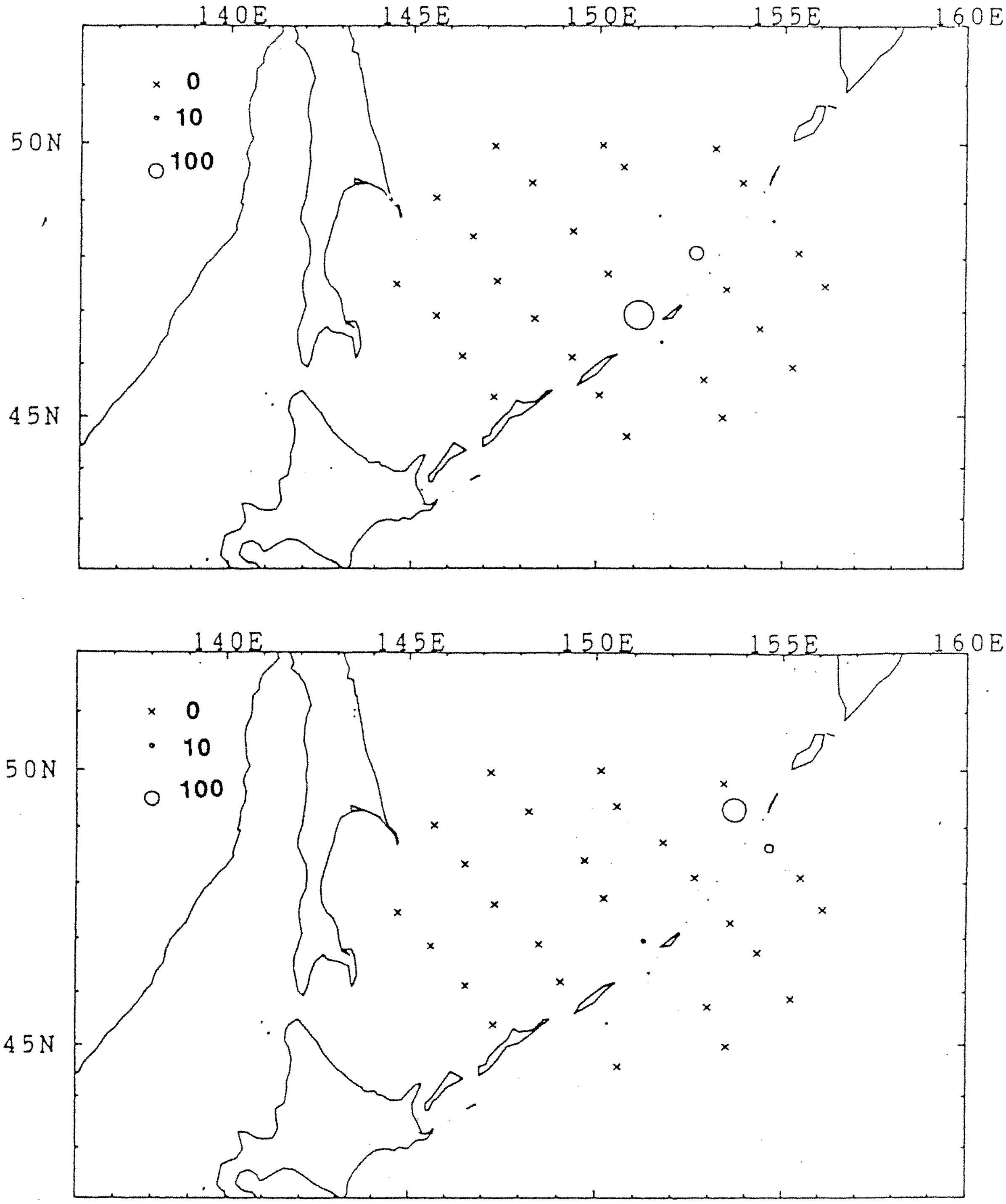


Fig. 5. Charts showing catches of Atka mackerel during October (upper) and November (bottom), 1993.

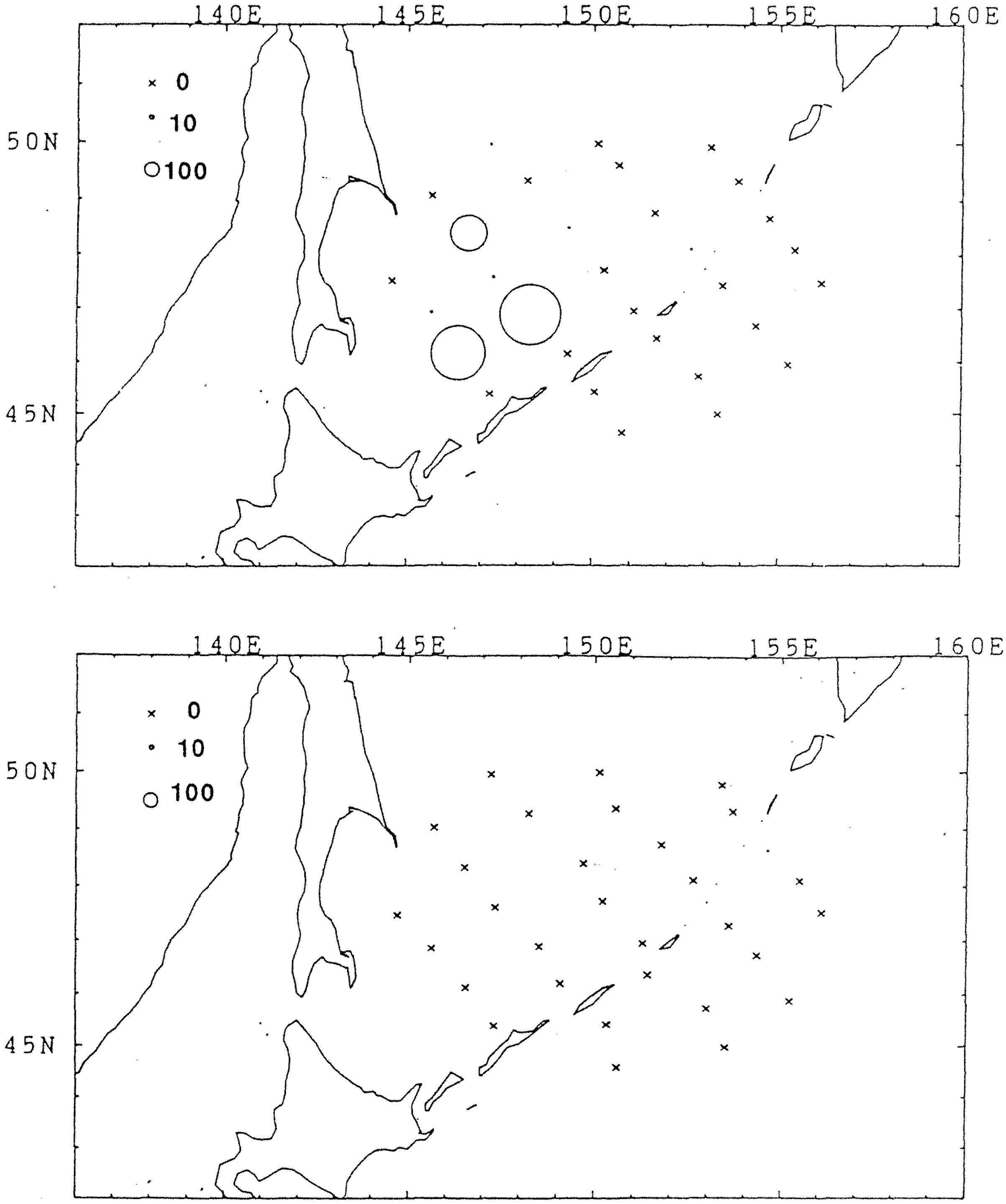


Fig. 6. Charts showing catches of arabesque greenling during October (upper) and November (bottom), 1993.

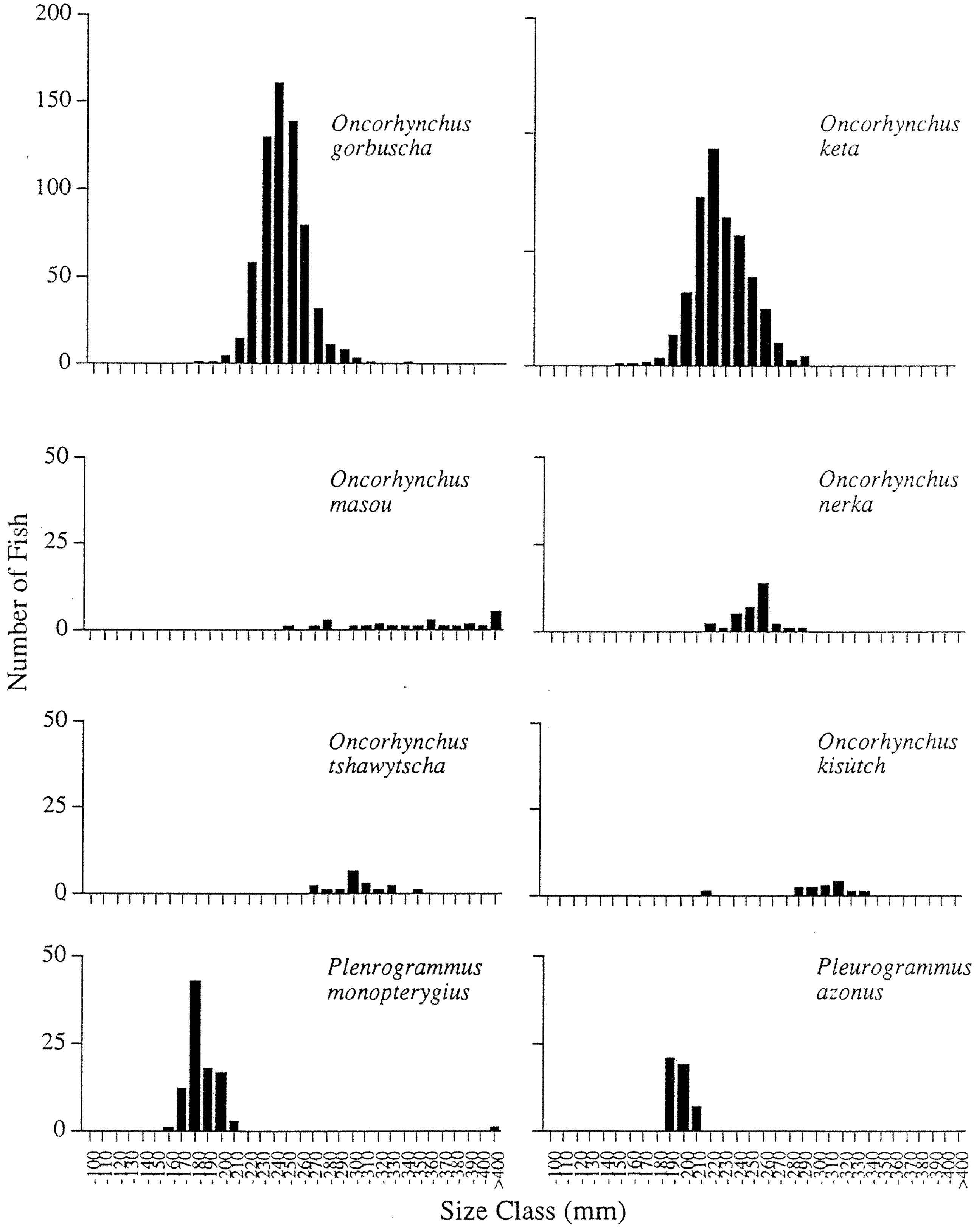


Fig. 7. Body length frequencies of juvenile salmon (fork length) and greenling (standard length), of which stomachs were examined.

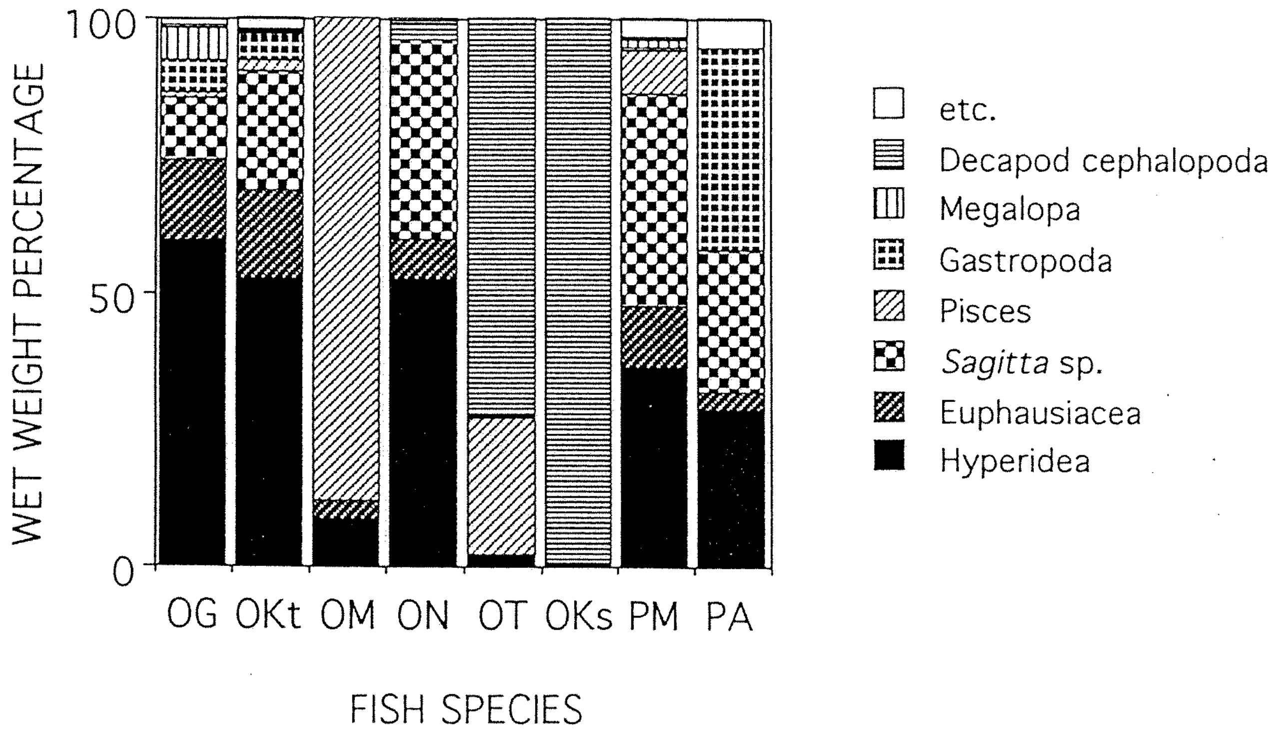


Fig. 8. Prey species composition of salmon and greenling presented as percentages in wet weight of the stomach contents.

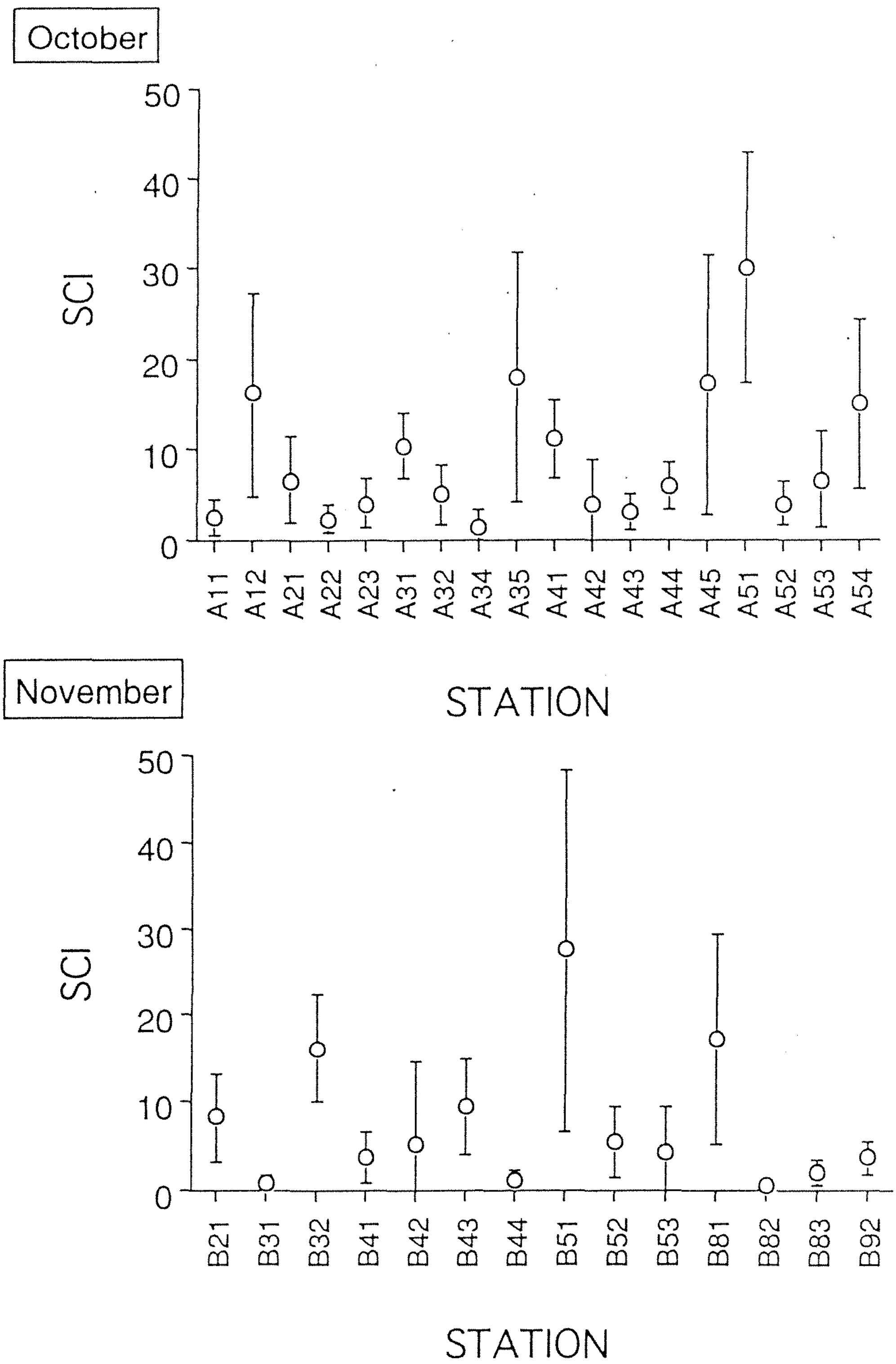
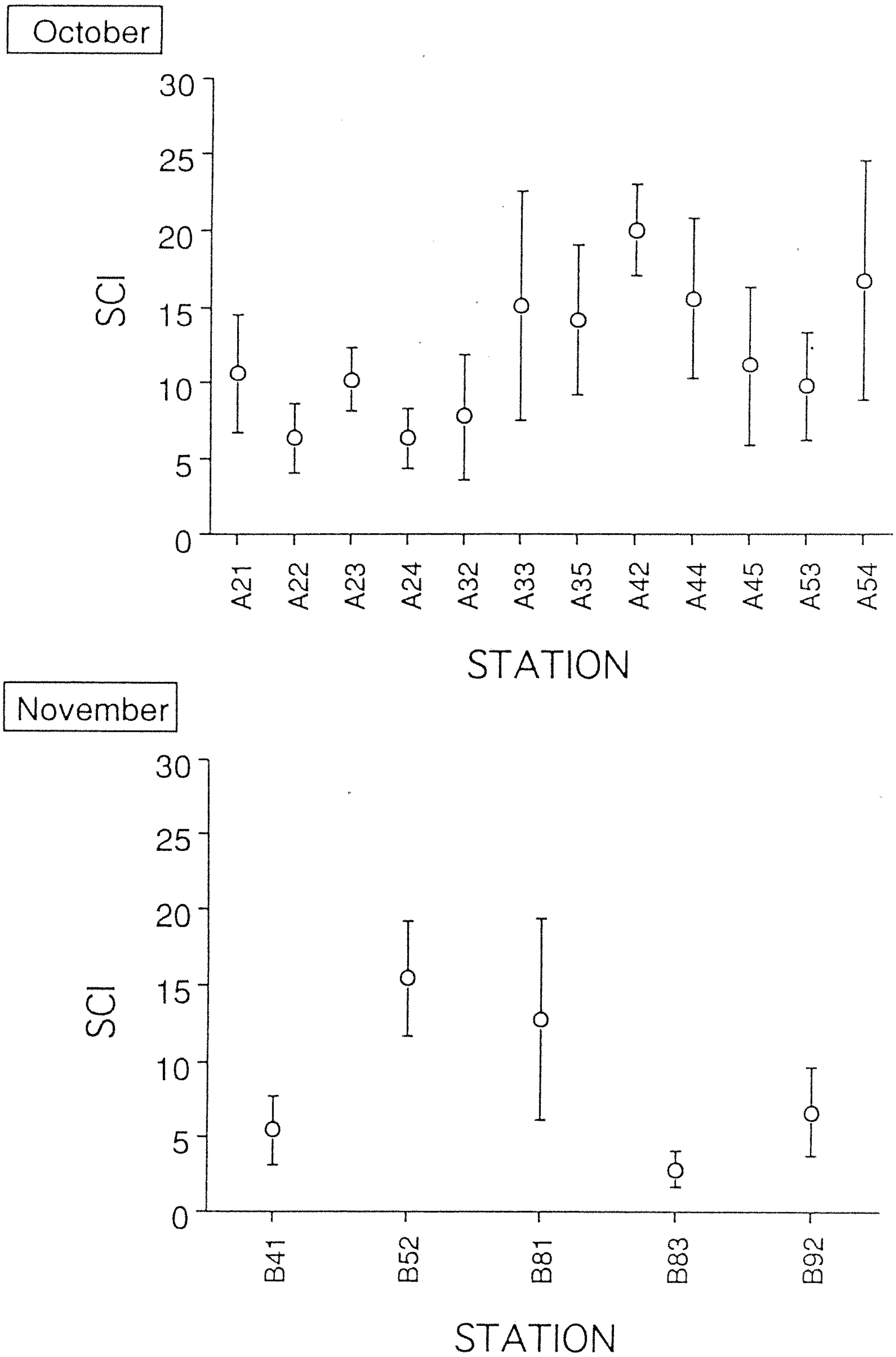


Fig. 9. Stomach content index (SCI=(stomach content weight)/(body weight)X10^3) of pink salmon collected at each station in the central and southern Okhotsk Sea and Pacific coast off Kuril Islands. during Ocotber (upper) and November (bottom); Error bar =±SD.



Fi Fig. 10. Stomach content index index (SCI=(stomach content weight)/(body weight)X10^3) of chum salmon collected at each station in the central and southern Okhotsk Sea and Pacific coast off Kuril Islands. during Ocotber (upper) and November (bottom); Error bar =±SD.

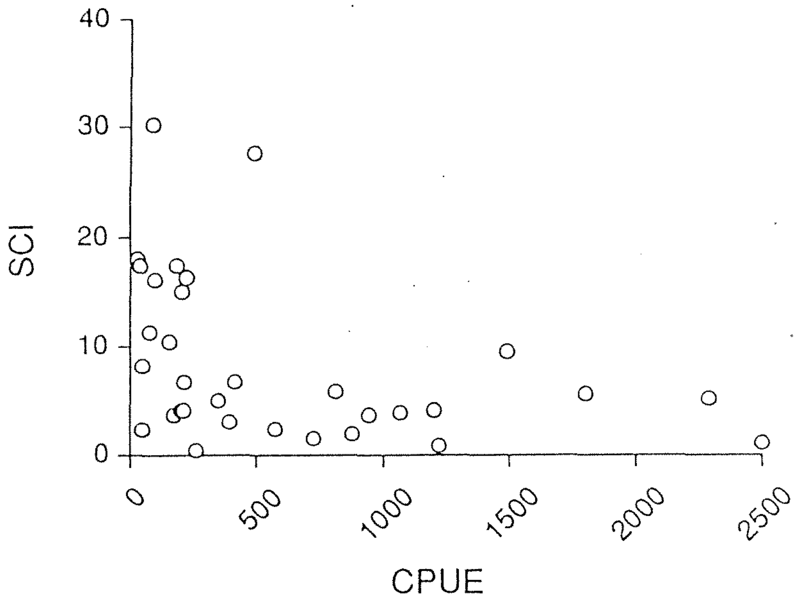


Fig. 11. Scatter diagram showing relationship between CPUE and stomach content index for pink salmon collected in the southern Okhotsk Sea and the Pacific coast waters of the Kuril Islands during October and November, 1993.

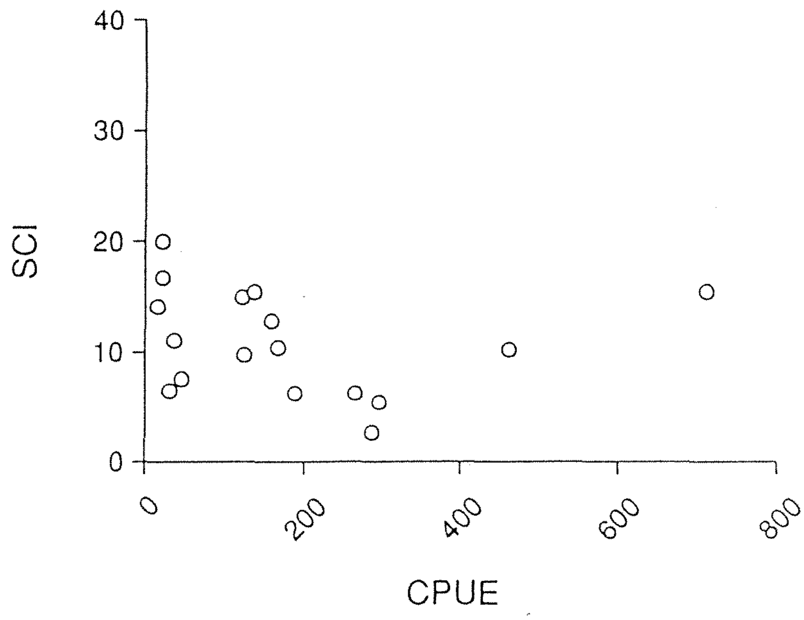


Fig. 12. Scatter diagram showing relationship between CPUE and stomach content index for chum salmon collected in the southern Okhotsk Sea and the Pacific coast waters of the Kuril Islands during October and November, 1993.

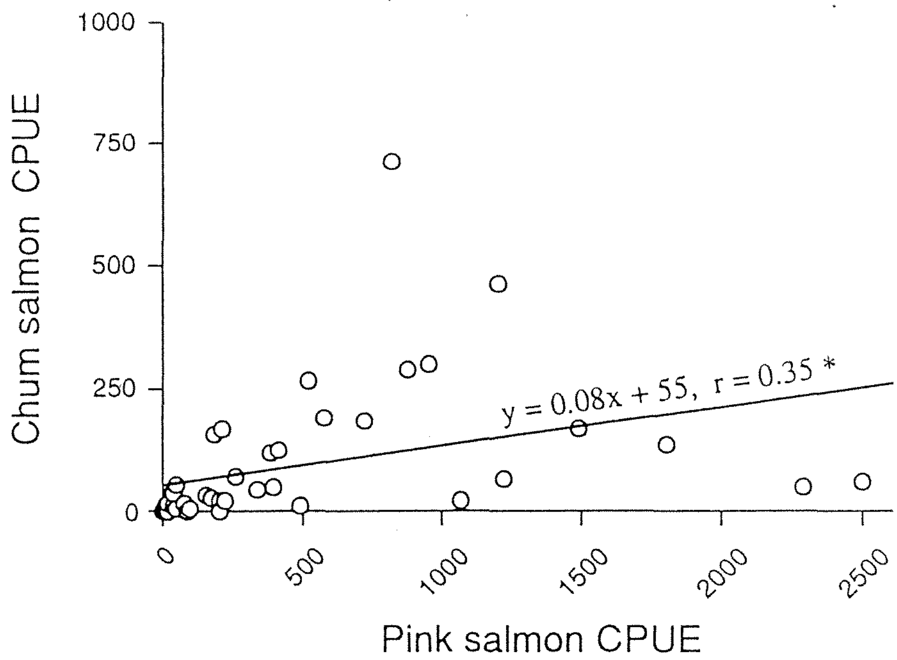


Fig. 13. Scatter diagram showing relationship between CPUEs of pink and chum salmon.

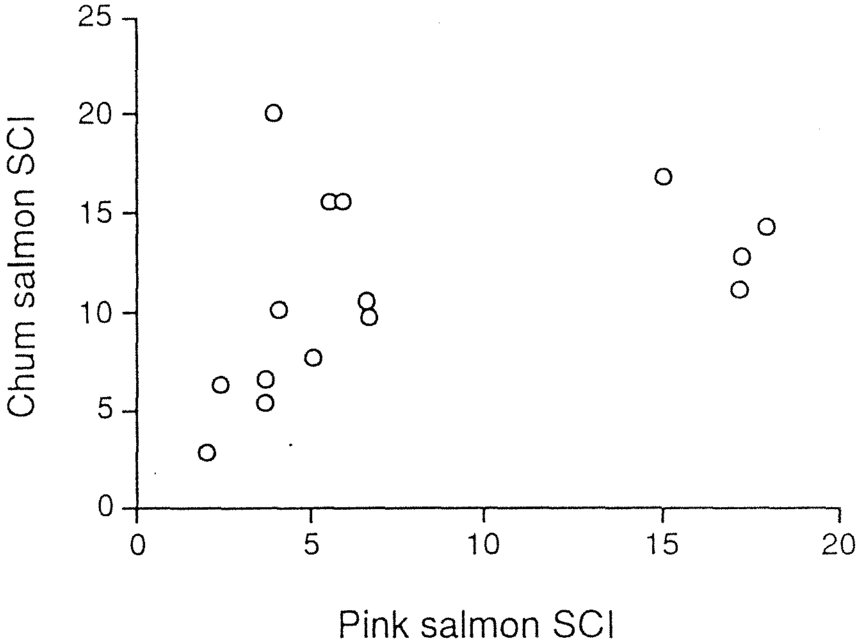


Fig. 14. Scatter diagram shhowing relationship between stomach content indices of pink and chum salmon.

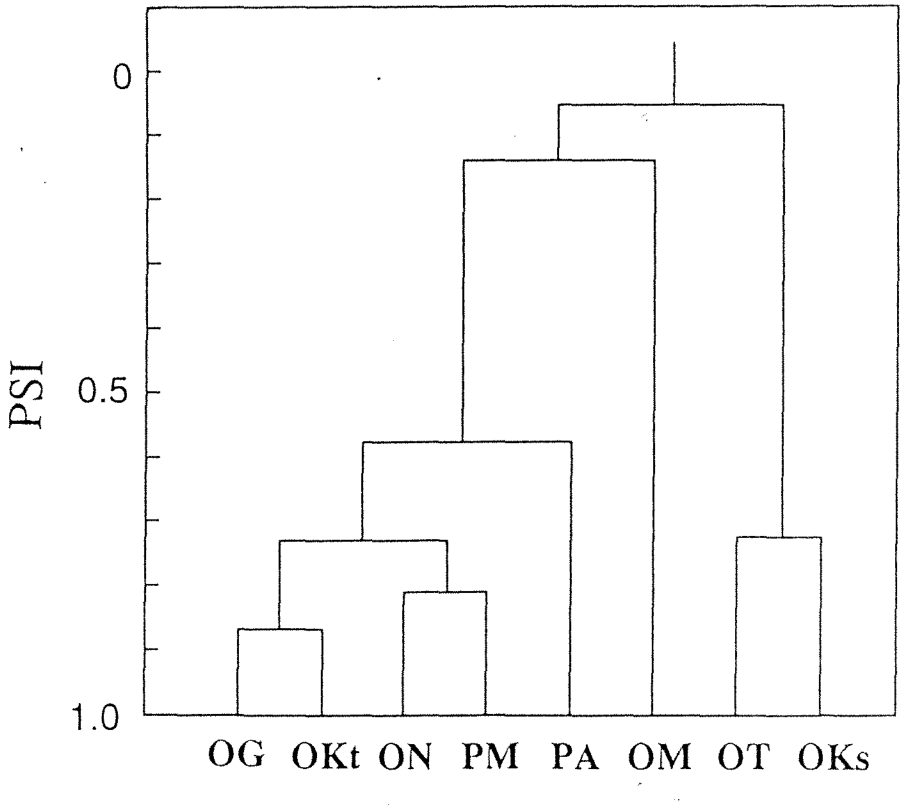


Fig. 15. Dendrogram shgowing the relationship in prey species composition among salmon and greenling based on the percent similarity index (PSI). (Abbreviations, OG: pink salmon, Okt: chum salmon, ON: sockeye salmon, PM: Atka mackerel, PA: arabesque greenling, OM: masu salmon, OT. Chinook salmon, Oks: coho salmon.)

Table 1. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of pink salmon collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

	N1/N2	637 / 553
	W1/W2	850.1 / 680.0
Prey item	W	F
Gastropoda	6.15	22.97
Gonatidae	0.76	1.81
Copepoda (unid.)	0.40	15.37
Calanus plumchrus	0.06	1.08
Hyperidea	1.30	12.84
Themisto sp.	41.24	86.26
Primno sp.	16.88	69.08
Vivilia sp.	0.09	8.68
Euphausiacea	2.29	12.30
Euphausiacea (Larvae)	0.09	14.10
Euphausia sp.	0.02	0.36
Euphausia pacifica	1.76	11.39
Thysanoessa sp.	0.14	2.35
Thysanoessa inermis	0.19	1.27
Thysanoessa longipes	9.98	6.51
Sergestes similis	0.45	1.63
Brachyura (megalopa)	5 .65	17.00
Sagitta sp.	11.36	37.43
Pisces (unid.)	0.13	1.27
Engraulis japonicus	0.08	0.18
Fish larvae	0.97	5.79
Terrestrial Insects	0.01	3.44

Table 2. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of chum salmon collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	424 / 398	
W1 / W2	585.1 / 247.8	
Prey item	W	F
Gastropoda	4.83	5.78
Decapod cephalopoda	0.65	1.01
Gonatidae	0.09	0.50
Copepoda (unid.)	1.12	14.07
Calanus plumchrus	0.30	0.75
Hyperidae	1.28	7.04
Themisto sp.	30.15	91.71
Primno sp.	21.0	73.87
Vivilia sp.	0.12	9.30
Euphausiacea	5.38	9.55
Euphausiacea (Larvae)	0.57	13.82
Euphausia sp.	0.11	2.51
Euphausia pacifica	2.54	4.52
Thysanoessa sp.	2.69	1.51
Thysanoessa inermis	1.20	1.76
Thysanoessa longipes	3.64	1.51
Sergestes similis	0.19	0.75
Brachyura (megalopa)	0.28	4.02
Sagitta elegans	21.62	51.51
Fish larvae	2.15	5.78
Terrestrial insects	0.02	2.26

Table 3. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of masu salmon collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	25 / 19	
W1 / W2	169.3 / 169.0	
Prey item	W	F
Themisto sp.	1.21	15.78
Euphausia pacifica	0.77	26.31
Thysanoessa inermis	2.72	5.26
Pisces (unid.)	15.56	26.31
Engraulis japonicus	67.24	31.57
Leurogrossus schmidti	7.01	5.26
Myctophidae sp.	5.51	5.26

Table 4. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of sockeye salmon collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	33 / 27	
W1 / W	30.3 / 28.4	
Prey item	W	F
Gastropoda	0.07	14.81
Gonatidae sp.	3.41	3.70
Calanoida (unid.)	0.49	7.41
Themisto sp.	38.50	100
Primno sp	14.09	88.89
Euphausiacea (unid.)	0.13	7.41
Euphausiacea (larva)	0.09	11.11
Euphausia pacifica	5.41	40.74
Thysanoessa inermis	1.47	3.70
Brachyura (megalopa)	0.05	3.70
Sagitta elegans	36.29	81.48

Table 5. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of chinook salmon collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	17 / 12	
W1 / W2	34.1 / 29.8	
Prey item	W	F
Gastropoda	0.03	16.67
Gonatidae sp.	72.41	66.67
Themisto sp.	0.11	25.00
Primno sp.	1.78	66.67
Brachyura (megalopa)	0.36	16.67
Sagitta elegans	0.10	8.33
Pisces (unid.)	25.21	8.33

Table 6. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of coho salmon collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	14 / 14	
W1 / W2	56.2 / 56.2	
Prey item	W	F
Gonatidae sp.	99.48	92.86
Themisto sp.	0.40	28.57
Primno sp.	0.12	21.43

Table 7. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of Atka mackerel collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	95 / 90	
W1 / W2	52.5 / 40.9	
Prey item	W	F
Gastropoda	0.26	5.56
Gonatidae sp.	0.73	6.67
Calanoida (unid.)	3.20	65.56
Neocalanus cristatus	0.32	12.22
Hyperidea (unid.)	0.96	14.44
Themisto sp.	25.73	92.22
Primno sp.	9.48	42.22
Euphausiacea (unid.)	9.17	16.67
Euphausiacea (larvae)	0.25	3.33
Euphausia sp.	0.71	5.56
Euphausia pacifica	1.23	4.44
Brachyura (megalopa)	1.39	15.56
Sagitta elegans	38.48	75.56
Pisces (unid.)	8.09	38.89

Table 8. Percentage of wet weight (W), percentage occurrence frequency (F), of prey species or categories in the stomachs of arabesque greenling collected in the southern Okhotsk Sea and the Pacific coast waters off Kuril Islands during October and November, 1993. N1: number of stomachs examined, N2: number of stomachs with identifiable contents, W1: total weight of stomach contents examined, W2: Total weight of identifiable stomch contents.

N1 / N2	47 / 46	
W1 / W 2	30.0 / 27.4	
Prey item	W	F
Gastropoda	36.59	2.17
Calanoida (unid.)	5.45	54.35
Hyperidea (unid.)	1.08	23.91
Themisto sp.	25.56	97.83
Primno sp.	0.16	17.39
Vivilia sp.	1.80	10.87
Euphausiacea (unid.)	1.61	21.74
Euphausiacea (larvae)	0.15	28.26
Euphausia pacifica	1.51	10.87
Sagitta elegans	26.00	84.78
Pisces larvae	0.07	8.70

Table 9. Matrix showing the percent similarity index (PSC) of prey species in the stomachs among salmon and greenling. (Abbreviations, OG: pink salmon, Okt: chum salmon, ON: sockeye salmon, PM: Atka mackerel, PA: arabesque greenling, OM: masu salmon, OT. Chinook salmon, Oks: coho salmon.)

	PA	PM	OKs	OT	ON	OM	OKt	OG
OG	0.52	0.64	0.02	0.05	0.72	0.21	0.86	
OKt	0.62	0.75	0.02	0.06	0.83	0.23		+++
OM	0.22	0.29	0.01	0.27	0.20		+	+
ON	0.61	0.82	0.04	0.06		-	+++	+++
OT	0.05	0.13	0.73		-	+	-	-
OKs	0.03	0.03		+++	-	-	-	-
PM	0.63		-	-	+++	+	+++	++
PA		+++	-	-	+++	+	+++	++