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by

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Abstract

The distribution and biological characteristics of juvenile chum and pink salmon were investigated in the Sea of Okhotsk during 13-31 October 2000. The research cruise was made using the research vessel *Torishima* (452 gross tonnage), equipped with a mid-water rope trawl. Of 23 surveys attempted in the cruise, only 11 were successfully conducted because of extremely bad weather conditions. Juvenile chum and pink salmon were distributed in the central water of the Sea of Okhotsk ranging from 48 to 51°N, whereas neither juvenile chum nor pink salmon were caught in the southern part of the sea. CPUEs of juvenile chum salmon were correlated with those of juvenile pink salmon. Mean fork lengths of both species varied among stations in a similar trend; at stations where mean fork lengths of chum salmon were small, those of pink salmon also small, and the opposite was also true. In addition, the mean fork lengths of both species were larger in the eastern part than in the western part. These findings indicate that juvenile chum and pink salmon prefer similar environmental conditions in the Sea of Okhotsk and that habitat overlaps of both species are probably common in this life stage. Oceanographic conditions such as the surface temperature and the depth of the thermocline also affected the distribution of juvenile salmon. In particular, there was a tendency that juvenile salmon were abundant in areas

where the thermocline was deep. Most of the results obtained in the present study confirmed those of previous studies conducted in the Sea of Okhotsk, in spite of limited sampling occasions.

Introduction

The assessment of salmon stock abundance in offshore waters is important to elucidate mechanisms of year-to-year variation in salmon production (Ueno and Sakai, 1997). Japan-origin salmon, however, are distributed in extended areas of all northern North Pacific Ocean and its marginal seas (Yonemori 1975; Neave et al. 1976; Salo 1991; Ogura 1994), which causes difficulty in estimation of the salmon stock abundance.

Recently, some researches suggest that a large number of Japan-origin juvenile salmon migrate into the Sea of Okhotsk after leaving Japanese coastal waters and that they grow up there during summer and mid-autumn (e.g., Ueno and Sakai 1997, Ueno 1997a). Since juvenile salmon in the Sea of Okhotsk are regarded as survivors from the coastal life, during which their mortality is probably the highest (e.g., Healey 1982, Watanabe 1999), there are some possibilities that we can assess the strength in year-class abundance of Japan-origin salmon in this area.

In this paper, we presented information on the distribution and biological characteristics of juvenile salmon collected in the Sea of Okhotsk during 13-31 October 2000. Furthermore, the results were compared with those of previous studies conducted in the same area in order to obtain more general information.

Materials and Methods

Research vessel and cruise: This research cruise was conducted using the research vessel (R/V) *Torishima* (452 gross tonnage) that belonged to Tankai-senpaku Co. (Tokyo, Japan). The R/V *Torishima* was classified into the stern trawler equipped with a CTD recorder. The research period extended from 13 to 31 October, during which we put in at Abashiri Port on 19 October so that two Japanese scientists left the R/V *Torishima* for another mission. Twenty three surveys had been attempted over the Sea of Okhotsk (46°00´- 52°00´N, 146°00´ - 152°00´E) and Pacific Ocean off the Kuril Islands (44°00´ N, 150°00´ E), but we carried out the surveys at only 11 stations owing to extremely bad weather conditions (Fig. 1).

Sampling gears and operation: A mid-water rope trawl was used for collection of juvenile salmon. The sizes of the trawl were 87 m in net length and 41 m in head-rope length. Maximum and minimum mesh sizes were 15 m and 45 mm, respectively, with a 16-mm mesh being used at the cod end. The trawl was towed for 60 min at average 3.5 knot. For each trawl operation, two portable depth meters were attached at the head- and grand-ropes to monitor depths of the each rope at an interval of one second. According to results of the depth meters, the average depth of the head-rope was 4.2 m and the average height at the mouth of the net was 18 m during the trawl operations.

Oceanographic observation and zooplankton sampling: CTD observation was conducted from 0 to 500 m in depth at all trawl stations. Zooplankton samples were collected using NORPAC and ORI nets at stations where trawl operations were conducted at sunset (total 5 stations). The NORPAC net was vertically retrieved from 150 m to the surface at 1 m/s. The ORI net was towed just under the surface for 10 min at 1 knot. Samples were preserved at 10% formalin.

Biological measurements: Captured salmonids were preserved in a deep freeze (-35º) until analyses on land. In laboratory, thawed specimens were sorted according to species. They were measured for fork length (nearest 1 mm), weighed (nearest 0.1 g), and dissected for sex determination. In some specimens, liver, heart, muscle, stomach contents and otolith were collected for further analyses such as genetic stock identification and otolith mark detection. Other by-catch species were sorted to species, counted and weighed on board.

Results

Distribution of salmonids: CPUE distributions of salmonids were shown in Figures 2 and 3. No juvenile chum and pink salmon were caught in the southern part of the Sea of Okhotsk. They were mainly distributed in the central water of the sea. Juvenile pink salmon were more abundant in the eastern part (150°E) than in the western part (146°E). The proportion of juvenile chum to pink salmon significantly differed among the stations ($?^2$ = 91.11, d.f. = 6, $p < 0.001$). However, there was significant correlation between CPUEs of both species ($r = 0.673$, $p < 0.05$). It seemed that masu salmon were distributed in the southern part of the Sea of Okhotsk not like juvenile chum and pink salmon, even though their CPUEs were extremely small. Coho salmon were only caught at the station 23 (50°N, 150°E).

Fork length of juvenile chum and pink salmon: Mean fork lengths (FL) of juvenile chum and pink salmon were demonstrated in Figure 4. Two-way ANOVA (factor; species and station) revealed significant effects of species and stations (species; $F_{1,1387} = 58.95$, p <

0.001 / station; $F_{6,1387} = 33.25$, $p < 0.0001$), with no interaction between the two factors being present ($F_{6,1387} = 0.96$, $p = 0.4490$); i.e., mean FLs of both species varied among stations with a similar trend although mean FLs of pink salmon were larger than those of chum salmon in all stations. Mean FLs of both species were larger in the eastern part than in the western part in the case when stations were grouped according to the longitude (one-way ANOVA: chum salmon, $F_{2,203} = 31.17$, $p < 0.0001$, Tukey-Kramer test; all combinations were significant. / pink salmon, $F_{2,1192} = 247.9$, $p < 0.0001$, Tukey-Kramer test; all combination were significant, see Fig. 2).

Relationship between water temperature and distribution of juvenile salmon: Vertical water temperature profiles (up to 150 m in depth) of the stations represented in Figure 5. The mean surface temperature of stations where juvenile salmon were captured (hereafter, juvenile salmon [JS] group) was 6.3°C, whereas that of stations where no juvenile salmon was found (hereafter, no juvenile salmon [NJS] group) was 10.8°C. The difference was significant between the two groups (Mann-Whitney test; $U = 2$, $p < 0.05$). Moreover, at five of seven stations of the JS group (71.4 %), the surface water temperatures ranged 4-6°C. Depths of the thermocline ranged from ˜ 30 to 100 m among the stations. In the JS group, the mean depth at the beginning of the thermocline was 57.0 m, whereas the value was 30.8 m in the NJS group. The mean depth also significantly differed between the JS and NJS groups (Mann-Whitney test; $U = 3$, $p < 0.05$). In addition, numbers of captured juvenile salmon were significantly correlated with depths at the beginning of the thermocline ($r = 0.856$, $p < 0.001$).

Discussion

This study showed that juvenile chum and pink salmon were distributed in the central water of the Sea of Okhotsk ranging from 48 to 51°N, whereas neither juvenile chum nor pink salmon occurred in the southern part of the sea. In addition, no juvenile salmon was also found in the North Pacific waters off the Kuril Islands although only one survey was executed in this area. Ueno and Sakai (1997) investigated distributions of juvenile salmon during late August and middle November 1996, using two R/Vs, Shunyo-maru (396.85 gross tonnage) and Kaiyo-maru (2, 630 gross tonnage), equipped with mid-water rope trawls. They reported that juvenile chum and pink salmon utilized the central waters of the Sea of Okhotsk as the summer and autumn nursery and that they began to migrate from the central to the southern part of the sea in the mid-late autumn (early October to middle November). Moreover, the other research cruises conducted in the Sea of Okhotsk also revealed the same results (reviewed by Ueno 1997a). The results of the present study confirmed those of the previous studies, but we could hardly recognize the southward migration owing to small numbers of surveys in the southern part.

The CPUEs of juvenile chum salmon were correlated with those of juvenile pink salmon, even though the proportion of both species differed among stations. Tamura et al. (1998) reported the same results in a previous research conducted in the Sea of Okhotsk during the autumn of 1993. These findings suggest that juvenile chum and pink salmon prefer similar environmental conditions in the Sea of Okhotsk and that habitat overlaps of both species are probably common in this life stage. Accordingly, mean FLs of juvenile chum and pink salmon demonstrated a similar trend among the stations; i.e., at stations where mean FLs of chum salmon were small, those of pink salmon also small, and the opposite was also true. In addition, mean FLs of both species were larger in the eastern part than in the western part. Taking the habitat overlaps of the two species into accounts, these results indicate that juvenile salmon having similar sizes occur in similar areas. A possible reason is that the distribution of juvenile salmon in the Sea of Okhotsk is influenced by the origin of them. Therefore, it is necessary to examine the relationship between the distribution of juvenile salmon and their origin in future studies.

In the present study, oceanographic conditions, especially the surface temperature and the depth of the thermocline, also affected the distributions of juvenile salmon. In particular, there was a tendency that juvenile salmon were abundant in areas where the thermocline was deep. Ueno (1997b), who conducted a juvenile salmon research in the Sea of Okhotsk during the early summer of 1997, also recognized a similar phenomenon. In the early-mid autumn, the upper layer of the thermocline showed relatively constant water conditions in the Sea of Okhotsk (Kono and Kawasaki 1995; Shimizu et al. 1995). Thus, a possible reason is that the thick upper layer facilitates the distribution and migration of juvenile salmon, as Ueno (1997a) pointed out. However, since the water temperature probably influences many other factors such as prey abundance and predator distributions, it is difficult to clarify which factor(s) determine(s) the distribution of juvenile salmon. To elucidate the relationship between the distribution of juvenile salmon and environmental factors such as vertical water conditions, it must be important to allow for not only direct relationships between them but also indirect ones including trophic relation between juvenile salmon and other organisms. The surface temperatures in stations where juvenile salmon occurred were similar to those of the previous studies (e.g., Ueno and Sakai, 1997, Tamura et al., 1998), indicating that juvenile salmon are distributed in cool waters (6-8°C) in the mid-autumn.

To estimate the abundance of juvenile salmon in the Sea of Okhotsk, the mid-late October may be one of suitable seasons because juvenile salmon still concentrate on the central of the sea. However, seasonal rough weather is common in this period, which would most likely hinder us from conducting effective surveys. Therefore, the early autumn, i.e., September, is probably better for future research cruises, as Ueno and Sakai (1997) recommended.

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References

Healey, M. C. 1982. Timing and relative intensity of size-selective mortality of juvenile chum salmon (*Oncorhynchus keta*) during early sea life. Can. J. Fish. Aquat. Sci. 39, 952-957.

Kono, T., and Y. Kawasaki. 1995. Development process of the surface mixed layer around the Kuril Islands from October to November. Salmon Report Series No. 40, 15-22. (In Japanese with English abstract.)

Neave F., T. Yonemori, and R. G. Bakkala. 1976. Distribution and origin of chum salmon in offshore waters of the North Pacific Ocean. Int. North Pac. Fish. Comm. Bull. 35, 1-79.

Ogura, M. 1994. Migratory behavior of Pacific salmon (*Oncorhynchus* spp.) in the open sea. Bull. Nat. Res. Inst. Far. Seas Fish. 31, 1-140. (In Japanese with English abstract.)

Salo, E. O. 1991. Life history of chum salmon (*Oncorhynchus keta*). In C. Groot and L. Margolis [ed.] Pacific salmon life histories. UBC Press, Vancouver. pp. 233-309.

Shimizu, I., J. Seki, Y. Ueno, Y. Kawasaki and T. Kono. 1995. Distribution of nutrients and chlorophyll a in the in the Okhotsk Sea and the Pacific Ocean off the Kuril Islands during the feeding migration of juvenile salmon. Salmon Report Series No. 40, 30-44. (In Japanese with English abstract.)

Tamura R., K. Shimazaki and Y. Ueno. 1998. Trophic relations of juvenile salmon (Genus *Oncorhynchus*) in the Okhotsk Sea and Pacific waters off the Kuril Islands. (NPAFC Doc. 331). National Research Institute of Far Seas Fisheries. 5-7-1 Orido, Shimizu, Shizuoka, 424, Japan. 33 p.

Ueno, Y. and J., Sakai. 1997. Distribution, biological characteristics and abundance estimation of Asian juvenile salmon in the Okhotsk Sea in the autumn of 1996. (NPAFC Doc. 268). National Research Institute of Far Seas Fisheries, 7-1, Orido 5-chome, Shimizu, Shizuoka, 424, Japan. 23 p.

Ueno, Y., 1997a. Distribution, migration, and abundance estimation of Asian juvenile salmon. (NPAFC Doc. 270) National Research Institute of Far Seas Fisheries, 7-1, Orido 5-chome, Shimizu, Shizuoka, 424, Japan. 17 p.

Ueno, Y., 1997b. Distribution and biological characteristics of juvenile salmon in the Sea of Okhotsk in the early-summer. (NPAFC Doc. 267) National Research Institute of Far Seas Fisheries, 7-1, Orid 5-chome, Shimizu, Shizuoka, Japan. 18 p.

Watanabe, T. 1999. Estimation of survival rate of juvenile chum salmon and evaluation of salmon ranching practice in Hokkaido, Japan. Bull. Natl. Salmon Resources Center 2, 29-37. (In Japanese with English abstract.)

Yonemori, T. 1975. A trial analysis of the results obtained from tagging on chum salmon originating from Hokkaido. Int. North Pac. Fish. Comm. Bull. 32, 130-161.

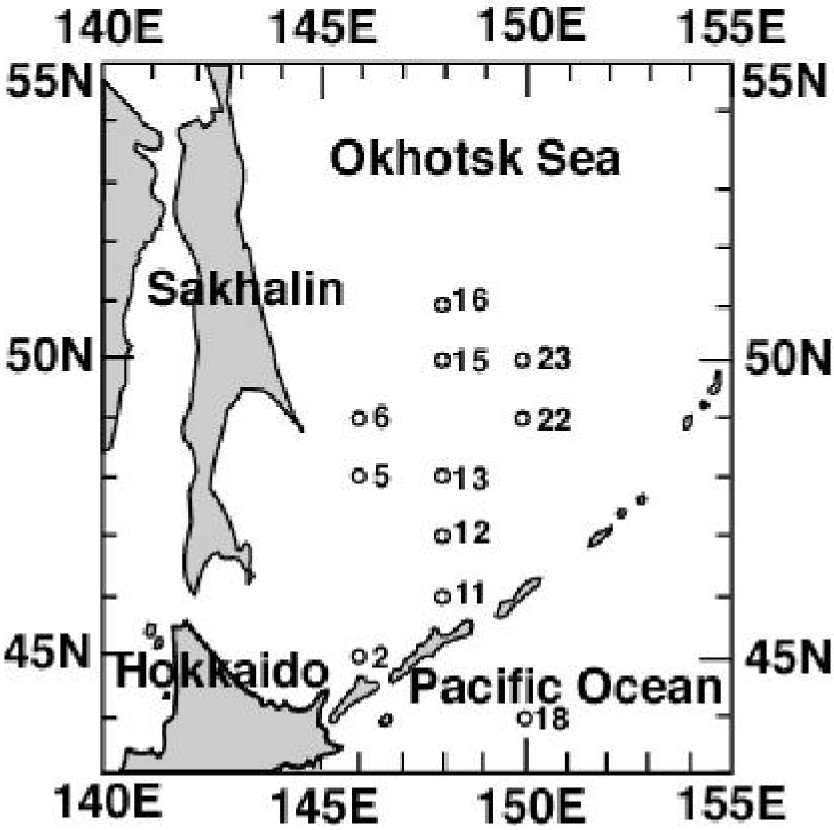

Fig. 1. Sampling stations where trawl operations and CTD measurement were conducted during the 2000 Torishima juvenile salmon research cruise.

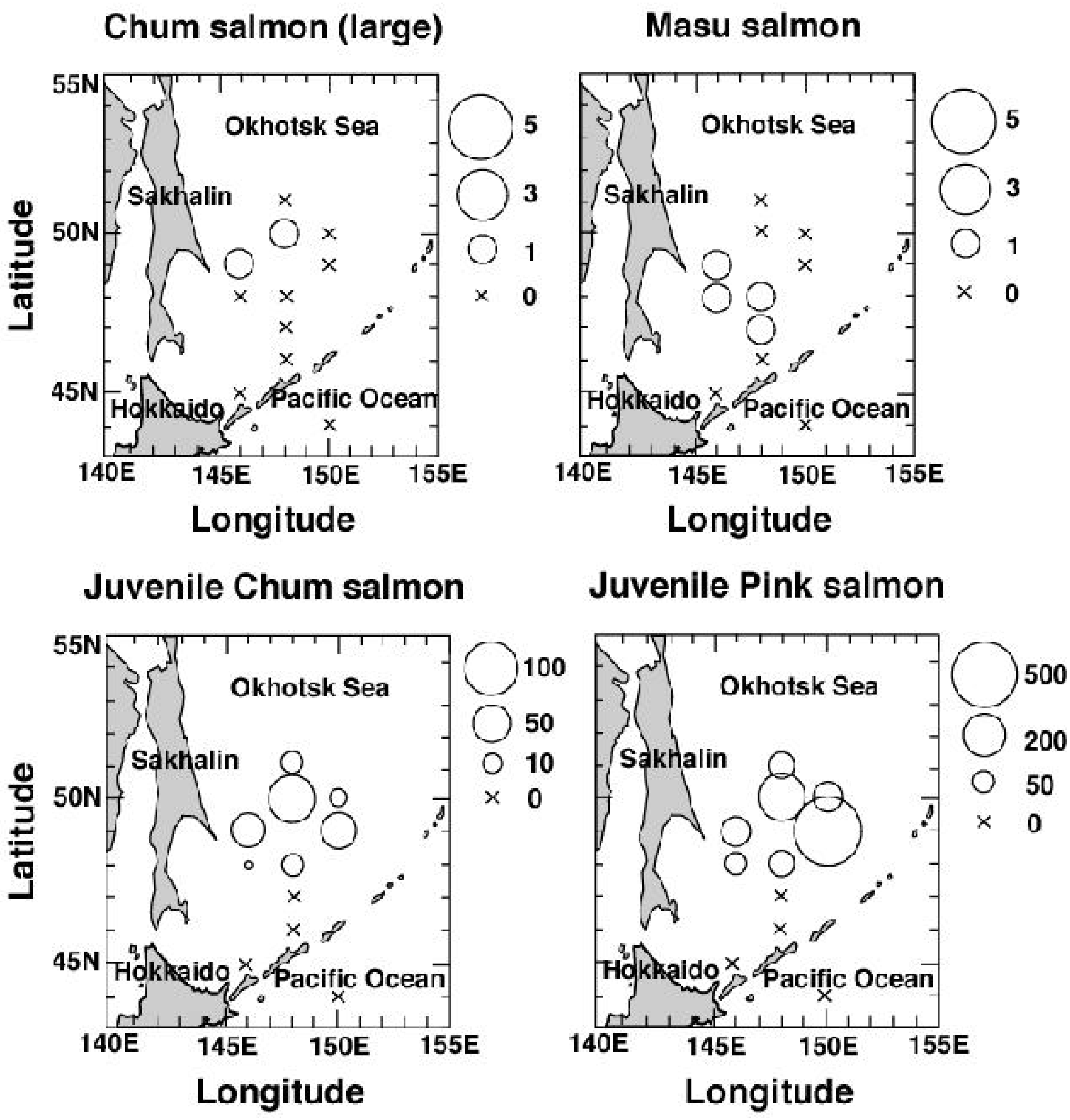

Fig. 2. CPUE distributions of chum, pink and masu salmon in the Sea of Okhotsk in the mid-late October of 2000. CPUE means the catch of fish per 1 h trawl at 3.5 nots.

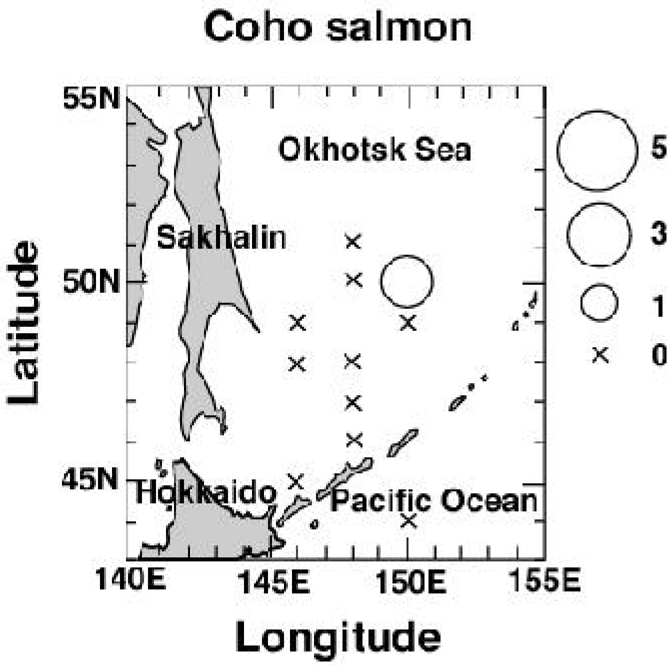

Fig. 3. CPUE distributions of coho salmon in the Sea of Okhotsk in the mid-late October of 2000. CPUE means the catch of fish per 1 h trawl at 3.5 nots.

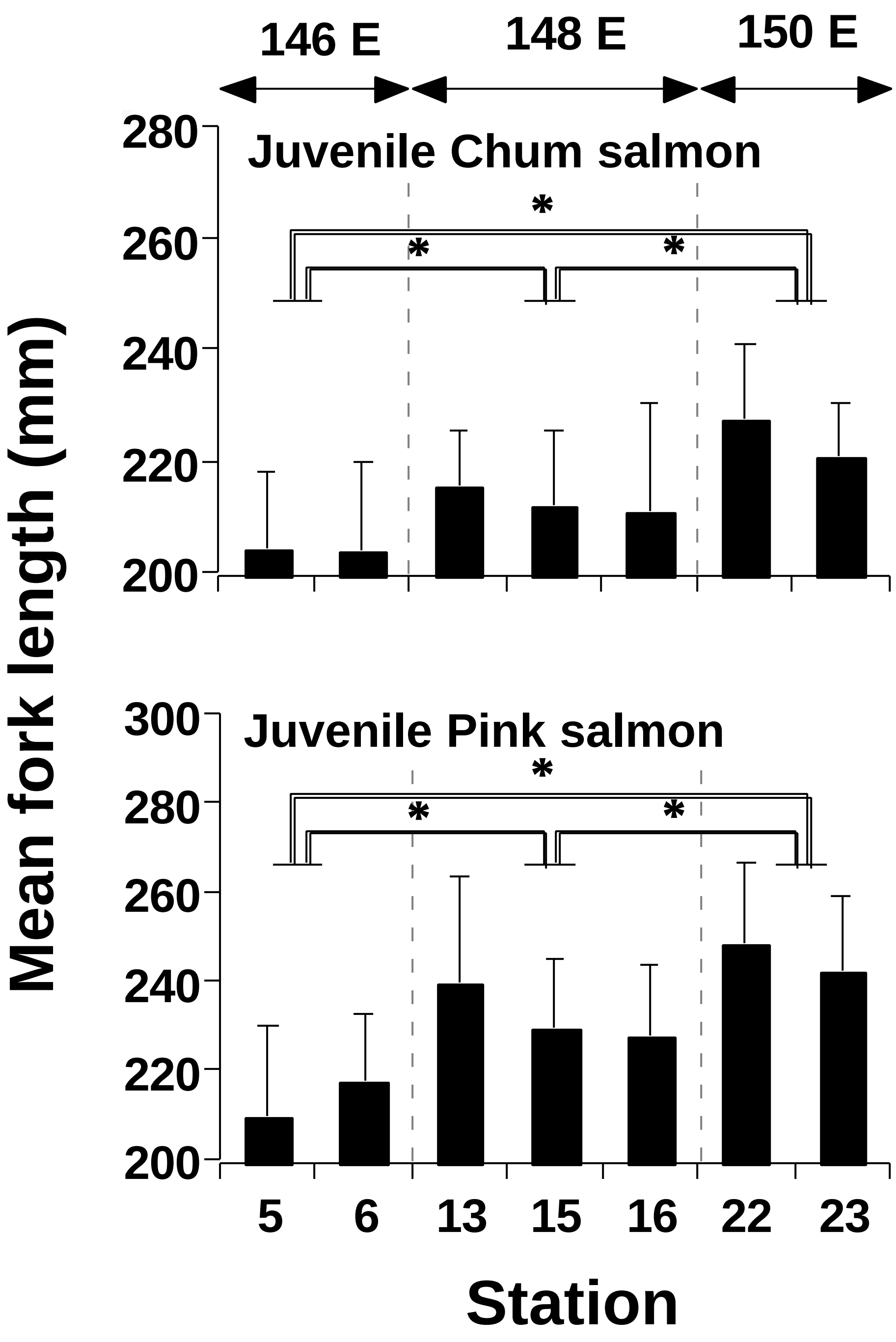

Fig. 4. Mean fork lengths of juvenile chum and pink salmon collected in the Okhotsk Sea during 13-31 October 2000. Bars indicate 1SE. Arrows represent longitude of stations. Asterisks demonstrate significant differences among longitudinal groups ($p < 0.05$).

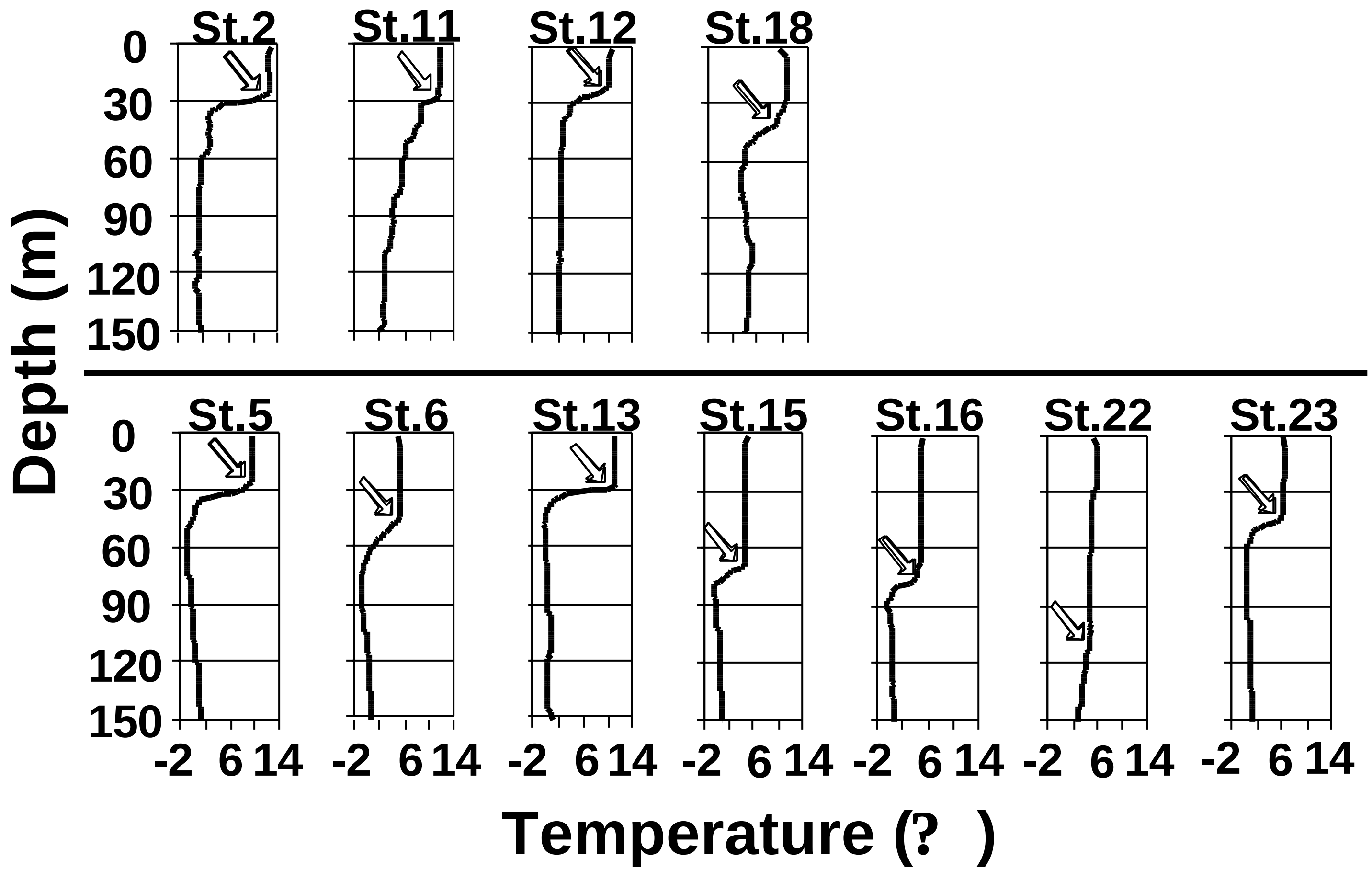

Fig. 5. Vertical profiles of water temperature in the Sea of Okhotsk during 13-31 October 2000. Open arrows indicate depths at the beginning of the thermocline. Upper graphs demonstrate results of stations where no juvenile salmon was captured. Lower ones represent those of stations where juvenile salmon were captured.

Appendix Table 1. Station, date and number of captured species on the trawl operations in the 2000 Torishima juvenile salmon research.

Station	Date	Latitude	Longitude	1	2	3	4	5	6	7	8	9	10	11	12	Total
St.2	2000.10.14	N45.00.1	E146.02.2	0	0	0	0	0	17	0	0	437	0	0	0	454
St.11	2000.10.15	N46.01.3	E148.00.3	0	0	0	0	0	0	0	0	7	1	0	1	9
St.12	2000.10.15	N47.00.6	E148.00.2	0	0	0	1	0	0	0	1	0	3	12	27	44
St.13	2000.10.17	N48.01.0	E147.59.3	15	0	75	1	0	0	0	0	0	1	0	0	92
St.5	2000.10.17	N48.00.5	E146.02.2	2	0	55	1	0	0	19	0	0	1	0	0	78
St.6	2000.10.22	N49.00.3	E146.02.9	43	1	90	1	0	0	0	0	0	0	0	0	135
St.16	2000.10.24	N50.59.7	E148.00.8	15	0	77	0	0	0	0	0	0	0	0	0	92
St.15	2000.10.25	N50.00.5	E148.00.0	82	1	267	0	0	0	0	0	0	1	0	0	351
St.22	2000.10.26	N49.00.5	E150.00.9	41	0	533	0	0	0	0	0	0	1	0	0	575
St.23	2000.10.26	N49.59.3	E150.01.6	8	0	98	0	2	0	0	0	0	0	0	0	108
St.24	2000.10.29	N44.02.0	E150.01.2	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	-	-	-	206	2	1195	4	2	17	19	1	444	8	12	28	1938

1:*Oncorhynchus keta* (juvenile), **2**:*O. keta* (mature/immature), **3**:*O. gorbuscha* (juvenile), **4**:*O. masou*, **5**: *O. kisutch*, **6**: *Todarodes pacificus*, **7**: *Gonatopsis borealis*, **8**: *Gonatus sp.*, **9**: *Cololabis saira*, **10**: *Pleurogrammus azonaus*, **11**: *Engraulis japonicus*, **12**: *Sebastes sp.*