Relationship between the Distribution of Juvenile Chum Salmon in the Coastal Waters of Eastern Hokkaido and Water Temperature as Determined by Experimental Releases of Otolith-Marked Juveniles

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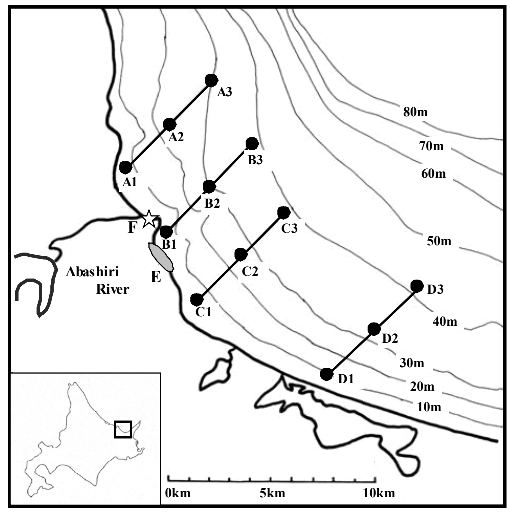
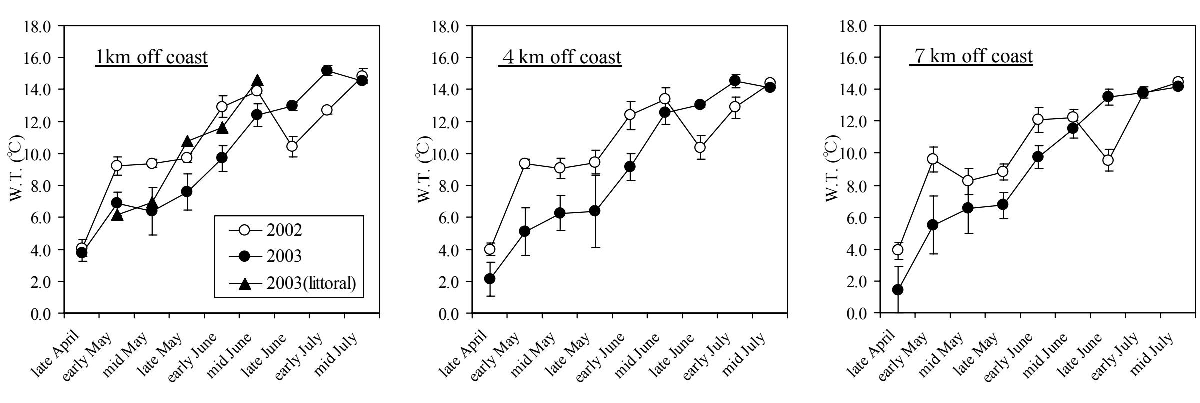
Numbers of hatchery-origin chum salmon in Hokkaido increased from ~10 million in the mid-1970s to ~40 million in the late 1980s. During the 1990s, returning chum salmon numbers fluctuated between 27 and 65 million with marine survivals varying between 2.6% and 5.9% despite at the same time there was a consistent annual release of ~1 billion juveniles from hatcheries (Nagata and Kaeriyama 2004). We started a project in 2002 to investigate marine mechanisms responsible for population fluctuations in hatchery-produced chum salmon. The otoliths of two million juveniles (46.6 mm mean fork length (FL)) were marked with 200 ppm ALC (alizarin complexone) solution at the fry eyed egg stage. These marked fish were released in mid-May 2002 into the Abashiri River where a total of 34 million hatchery juveniles were stocked every year. In 2003, 1.9 million (47.5 mm mean FL) and 1.4 million juveniles (47.6 mm mean FL) ALC-marked with different degree days were stocked in late April and mid-May, respectively. Twelve coastal sites (1–7km off the coast) as well as various temporary sites (mainly 2003) in littoral zones and in a fishing port were established in the Abashiri Bay of Okhotsk Sea to catch chum juveniles using a surface trawl net or beach seine (Fig. 1).

Fig. 1. Maps showing the study sites including the fishin port(F), littoral areas(E), 1 km, 4 km and 7 km off the Abashiri coast (A-D) in the Okhotsk Sea.



Surface seawater temperatures (SST) ranging from 8 to 13°C which are considered to be optimal for chum juveniles (Kaeriyama 1986; Irie 1990), were formed in the coastal waters from 1 km to 7 km off the coast during May and June in 2002. The early, warmer temperatures occurred because the Soya Warm Current arrived early (Fig. 2). In contrast, as the Soya Warm Current was delayed in 2003, a cold water mass < 8°C occupied the coastal waters in May. Nevertheless, the optimal SSTs from 7 to 11°C were found in the littoral zone and the fishing port.

Fig. 2. Changes in mean values with SD of SST at the littoral sites, the 1 km, 4 km and 7 km off the Abashiri coast in the Okhotsk Sea in 2002 and 2003.



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Unmarked chum juveniles were more abundant in the coastal waters from May to June in 2002, and first ALC marked juveniles were found 1 km off the coast in late May (Fig. 3). Although mean fork lengths of unmarked juveniles and ALC marked juveniles at every site tended to increase with elapsed time, fish 1 km off the coast were significantly smaller than those 4 and 7 km off the coast in June (Fig. 4). Bimodal fork length distributions were observed for unmarked juveniles from late May to mid June, but ALC marked juveniles showed unimodal length distribution and fell into the lower modal group in the length frequency distribution of unmarked juveniles, indicating that the upper modal group may have originated from the earlier stocked group, or were juveniles that grew fast and subsequently moved off the coast earlier (Nagata et al. 2004).

Fig. 3. Changes in CPUE (catch per unit effort, the number of juveniles per 2 km towing or per beach seine) of unmarked and ALC marked juvenile chum salmon captured at the littoral sites (beach seine), the 1 km, 4 km and 7 km off the Abashiri coast (trawl net) in the Okhotsk Sea in 2002 and 2003.

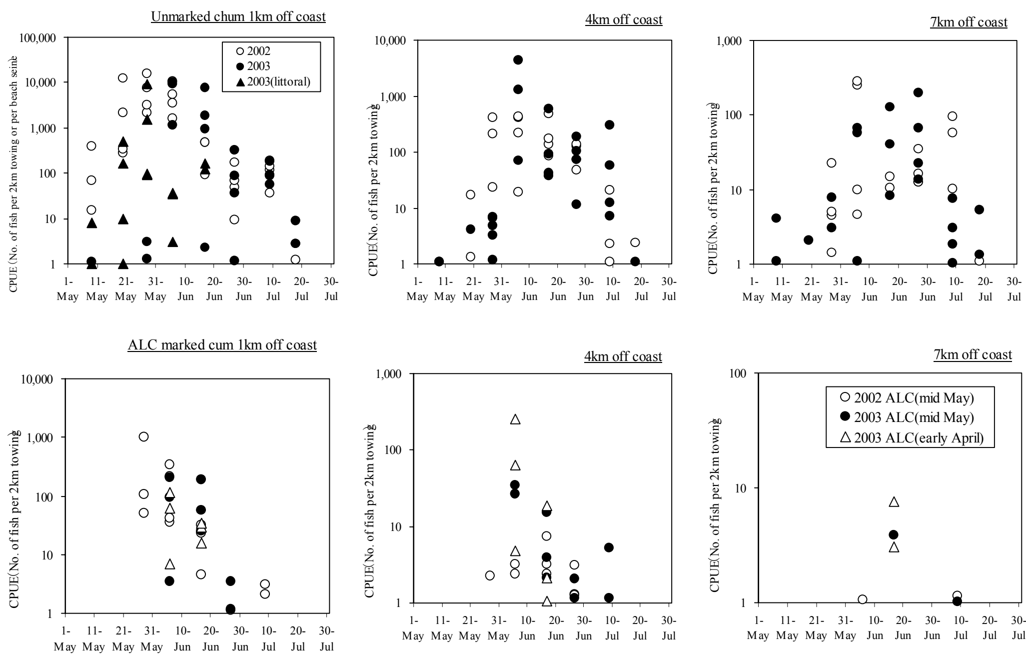
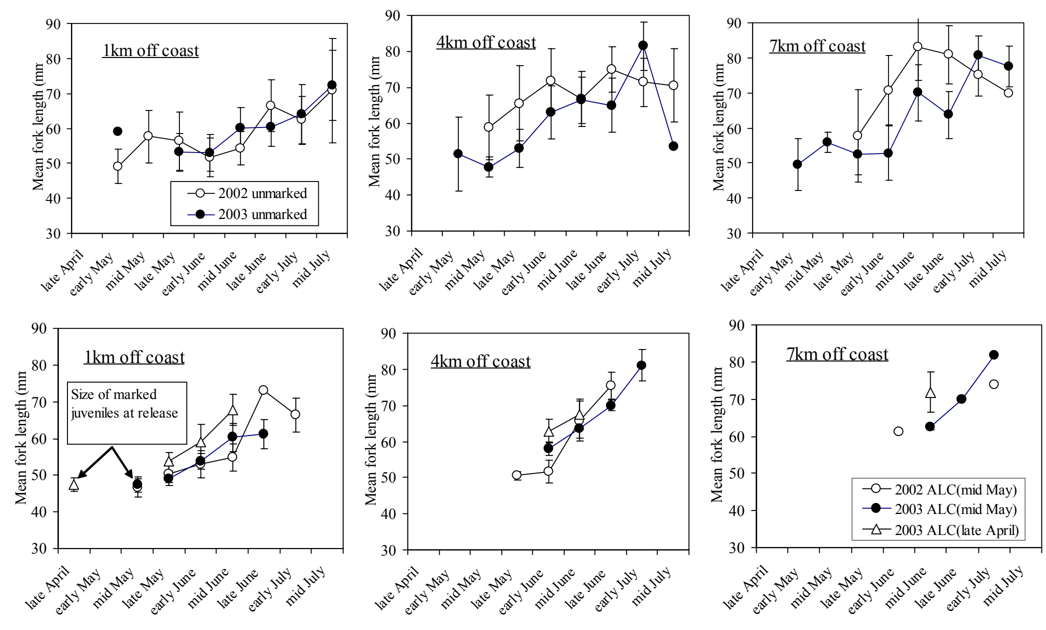


Fig. 4. Changes in mean fork length with SD of unmarked and ALC marked juvenile chum salmon captured at the 1 km, 4 km and 7km off the Abashiri coast in the Okhotsk Sea in 2002 and 2003.

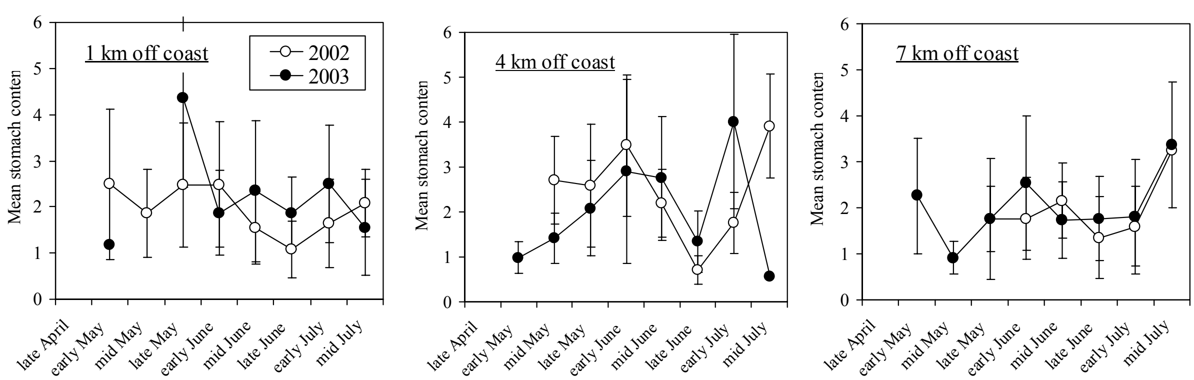


In contrast, most unmarked juveniles in 2003 occurred near the coast from early June, three weeks later than in 2002 (Fig. 3). ALC marked juveniles that were released early in late April 2003 were neither observed near the coast until early June, nor were the Late-stocked in mid May. The migration time for ALC marked juveniles in 2003 was ten days later than it was in 2002. More interestingly, many juveniles before moving to the coastal waters were found in littoral areas and the fishing port where SSTs were generally higher than in the coastal waters. This suggests that early-stocked juveniles stayed in the littoral zone for much longer than the late-stocked juveniles. Length frequencies of unmarked juveniles in 2003 remained unimodal until we finished our investigation, differing from the bimodal distribution in the 2002. Length frequency distributions of the two ALC marked groups overlapped, although mean fork length of early-stocked juveniles was 5 mm larger than that in late-stocked juveniles (Fig. 4). In addition, specific growth rate (SGR, 0.0051) for initial three weeks after stocking of early-stocked group in ALC marked juveniles 2003 captured 1km off the coast was lower than SGR (0.0062–0.0064) the late stocked groups in both years. Juveniles in both years rapidly disappeared from the coast after late June when SST > 13°C, although the earlier chum juveniles were stocked, the earlier they tended to move away.

Stomach content indices (stomach content weight x 100/body weight) for juvenile chum in both years were high in late May and early June, but they decreased in late June (Fig. 5). This decrease in stomach contents in both years was coincident with the rapid decrease in CPUE of juvenile chum and zooplankton abundance (Asami et al. 2005). Diet analysis revealed that juvenile chum salmon in the coastal waters in both years consumed primarily copepods (mainly *Pseudocalaunus newmani*) early in the season, switching to cladocerans (mainly *Podon leuckarti*, *Evadne nordmanni*) and appendicularians (mainly *Oikopleura longicauda*, *Fritillaria borealis* f. *typica*) as these became more abundant in the sea (Asami et al. 2005). Diet composition of chum juveniles that stayed in the littoral zone in 2003 was different from that in the coastal waters, especially for juveniles in the littoral zone. These individuals in the littoral zone consumed more epibenthic crustaceans such as Harpacticoida copepods and amphipods, indicating that juvenile chum can change feeding behavior depending on nursery conditions.

Estuary residence or offshore movement of chum salmon juveniles after downstream migration may depend on seawater temperature, rather than fish size. Cold water masses < 8°C may restrict their offshore movement, and fry may remain in the littoral zone for long periods. In fact, early-stocked juveniles in the 2003 used the littoral zone as a nursery area for several weeks despite abundant zooplankton in the coastal waters (Asami et al. 2005). Their long stay in the relatively small littoral zone might have caused a decrease in feeding activity and growth due to the shortage of food amount with highly dense population and/or low water temperature in early periods. If this is true, the difference in migration pattern between early and late stocked juveniles may affect survival in early ocean life. This hypothesis will be testified from the coming data. As ALC marked chum salmon stocked at the different periods in 2002 and 2003 will return as three to five years old from 2004 to 2007.

Fig. 5. Changes in mean values with SD of stomach content index (stomach content weight x 100/body weight) of juvenile chum salmon captured at the 1 km, 4 km and 7 km off the Abashiri coast in Okhotsk Sea in 2002 and 2003.



REFERENCES

Asami, H., H. Satoh, H. Shimada, M. Sawada, Y. Miyakoshi, D. Ando, and M. Nagata. 2005. Fluctuations of zooplankton community during early ocean life of chum salmon in the coastal waters of eastern Hokkaido, Okhotsk Sea. N. Pac. Anadr. Fish Comm. Tech. Rep. 6: 54–56.

Irie, T. 1990. Ecological studies on the migration of juvenile chum salmon, *Oncorhynchus keta*, during early life. Bull. Seikai Nat. Fish. Res. Inst. No. 68:1–142. (In Japanese with English abstract).

Kaeriyama, M. 1986. Ecological study on early life of the chum salmon, *Oncorhynchus keta* (Walbaum). Sci. Rep. Hokkaido Salmon Hatchery 40: 31–92. (In Japanese with English abstract).

Nagata, M. and M. Kaeriyama. 2004. Salmonid status and conservation in Japan. *In* The proceedings of world summit on salmon. *Edited by* P. Gallaugher and L. Wood. Simon Fraser University, B.C., Canada. pp. 89–97.

Nagata, M. and H. Asami, Y. Miyakoshi, and D. Ando. 2004. Spatial distributions of juvenile chum salmon in the coastal waters of eastern Hokkaido determined with otolith-marking in relation to zooplankton community. N. Pac. Anadr. Fish Comm. Tech. Rep. 5: 24–26.