Spatial Distributions of Juvenile Chum Salmon in the Coastal Waters of Eastern Hokkaido Determined with Otolith-Marking in Relation to Zooplankton Community

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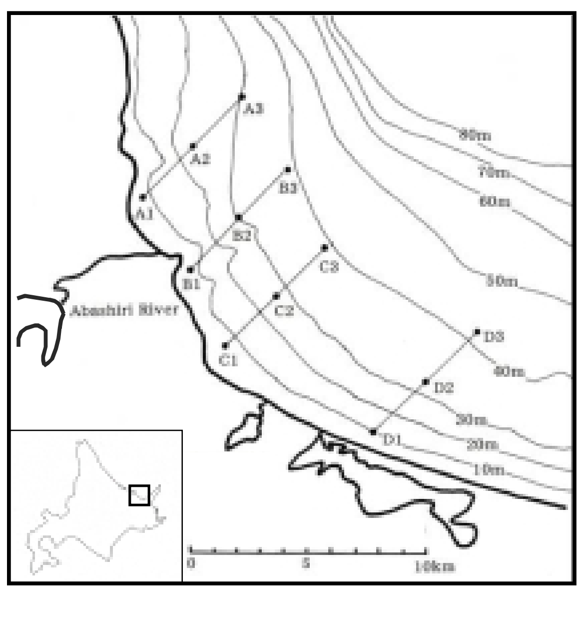
Keywords: ALC marking, hatchery chum salmon, spatial distribution and abundance, SST, zooplankton

The number of hatchery-origin chum salmon in Hokkaido increased from 10 million in the middle 1970s (brood year) to 40 million in the 1980s. During the 1990s, the chum population fluctuated between 27 and 65 million with return rates varying between 2.6% and 5.9%. There have also been great differences in return rates among chum returning to the Okhotsk Sea, the Japan Sea, and the Pacific Ocean. Recent return rates to the streams and coast of the Okhotsk Sea have been much higher than those in other areas. More interestingly, great differences in return rates between early and late run groups were found; return rates for early runs were higher than for late runs. We conclude that these fluctuations and differences are caused by coastal water conditions in relation to food production and predation. Hokkaido chum salmon populations have been maintained by hatcheries with similar numbers of juveniles released (approximately ten billion in Hokkaido) every year during the past twenty years. In contrast, wild salmon tend to fluctuate in recruitment. Therefore, we started a project in 2002 to clarify mechanisms responsible for population fluctuations in hatchery-produced chum salmon in relation to ocean conditions, especially the coastal environments. This project has been undertaken in collaboration with Hokkaido Fisheries Experimental Stations, Hokkaido Tokai University, and Hokkaido University. The project is comprised of three parts: zooplankton community structure, population dynamics of chum salmon, and prey-predator interactions.

We chose the Abashiri coast in the southwestern part of Okhotsk Sea to investigate the spatial distribution and abundance of juvenile chum salmon because there were large chum populations in the area that had highly variable survivals, but little recent information on chum salmon biology. On December 19–20, 2001, otoliths from chum salmon at the eyed egg stage in the Abashiri River were mass-marked with 200 ppm ALC (alizarin complexone) solution for 24 hrs in the Aioi Private Salmon Hatchery. ALC marking was used since it is very easy to detect the marks under a fluorescent microscope without polishing the otolith. In mid May 2002 we stocked two million otolith-marked (47 mm mean FL) juveniles in the Abashiri River where a total of 35 million hatchery juveniles were stocked in May. Twelve study sites were established in the Abashiri coastal waters (Fig. 1). Four sites were set up 1 km off coast (~ 10 m deep), near the shoreline. Four study sites were established at 4 km (20–30 m deep) and 7 km (30–40 m deep) off the coast.

Fig. 1. Maps showing the study sites 1 km, 4 km and 7 km off the Abashiri coast in the Okhotsk Sea.



Although the mean SST in late April was < 5 °C, temperatures rapidly increased and exceeded 8 °C in early May, and then increased gradually in June, eventually reaching to 14–15 °C in mid July when we finished our investigation (Fig. 2). A total of 60,000 chum juveniles were collected with a surface trawl net towed 2 km at 4–6 km·hr^{-1} from late April to mid July, 1–7 km off the coast. Approximately 2% of the catch were comprised of ALC marked juveniles. Most juvenile chum salmon were in the coastal waters where SST ranged between 9 and 14 °C. Although high CPUE (catch-per-unit effort; number of juveniles per 2 km towing) of unmarked chum

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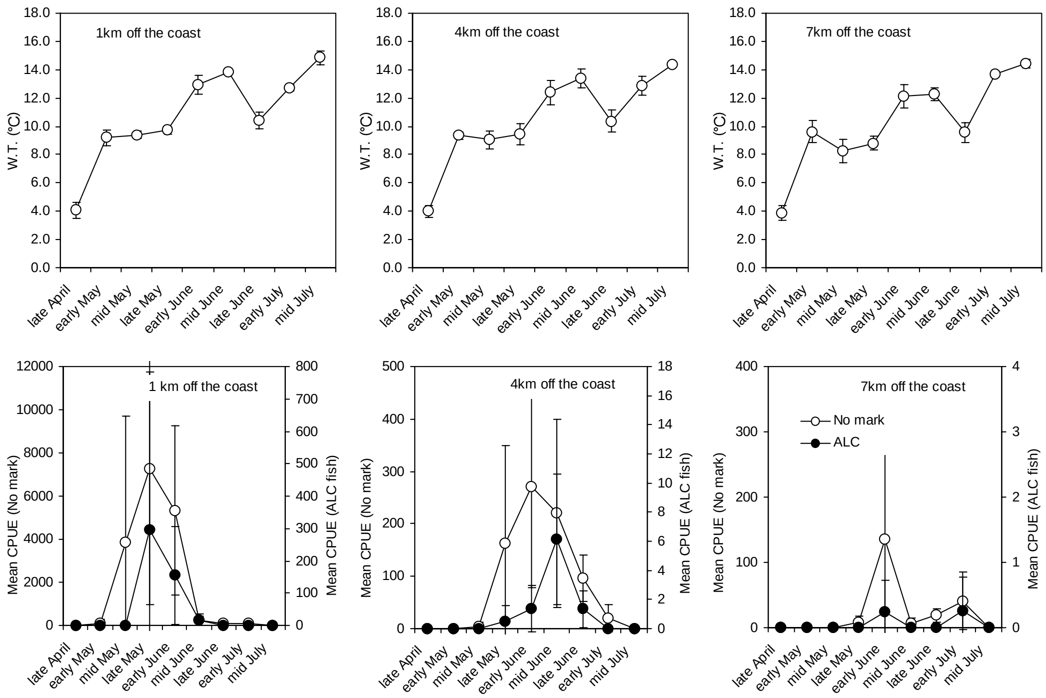
Fig. 2. Changes in mean values of SST and CPUE (catch per unit effort, the number of juveniles per 2 km towing) of no-marked and ALC marked juvenile chum salmon captured at the 1 km, 4 km and 7 km off the Abashiri coast in the Okhotsk Sea.



salmon was recorded at the four sites 1 km off the coast from mid May to early June, fish densities decreased rapidly afterwards (Fig. 2). In contrast, fish densities 4 and 7 km off the coast were much lower than at the sites 1 km off the coast, peak CPUEs occurred 10–20 days later, and densities decreased gradually after the peak. ALC marked juveniles were captured ten days after stocking. Marked juveniles showed similar patterns in fish abundance and distribution as unmarked fish. Fork lengths of juvenile chum salmon varied between 3 and 15 cm, with most from 4–8 cm. Although fork lengths at every site tended to increase with elapsed time, fish 1 km off the coast were significantly smaller than for those caught 4 and 7 km off the coast (Fig. 3). Although the fork length distribution of ALC marked juveniles was unimodal at the study sites, the length distribution of unmarked juveniles was bimodal or polymodal, indicating that groups of hatchery-produced fry emigrate at different times and/or grow at different rates.

Zooplankton were collected using a Norpac net (45cm mouth diameter, 0.33 mm mesh size) towed vertically from the bottom to the surface at each site. Zooplankton was most abundant in the inshore waters, 1 km off coast. Mean zooplankton abundance at all sites decreased gradually from May to July (Fig. 4). Copepods (mainly *Peudocalaunus newmani*) that predominated in May decreased in June when cladocerans (mainly *Podon leuckarti*, *Evadne nordmanni*) and appendicularians (mainly *Oikopleura longicauda*, *Fritillaria borealis* f. *typica*) numbers increased. Stomach content indices (stomach content x 100 / body weight) for juvenile chum were high in late May and early June, but they decreased rapidly in late June (Fig. 4). Diet composition by number showed juvenile chum salmon consumed mainly copepods early in the season, switching to cladocerans and appedicularians as these became more abundant in the sea.

We know from results from the same area twenty years previously that most chum salmon fry tended to occur in nearshore areas where SST was from 5 to 13 °C and subsequently

Fig. 3. Changes in mean fork length of no-marked and ALC marked juvenile chum salmon captured at the 1 km, 4 km and 7 km off the Abashiri coast in the Okhotsk Sea.

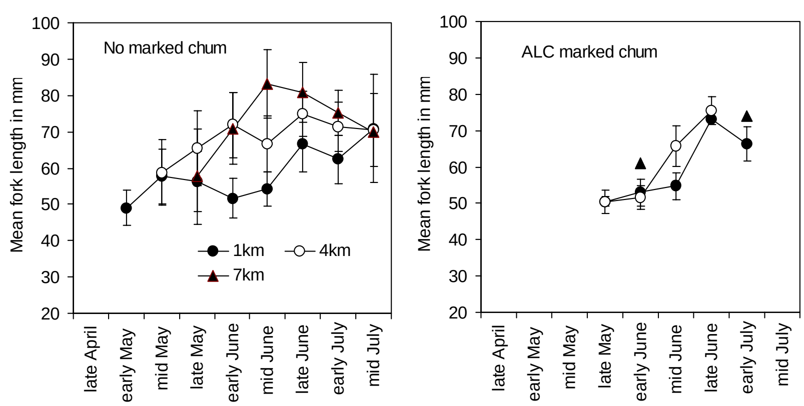
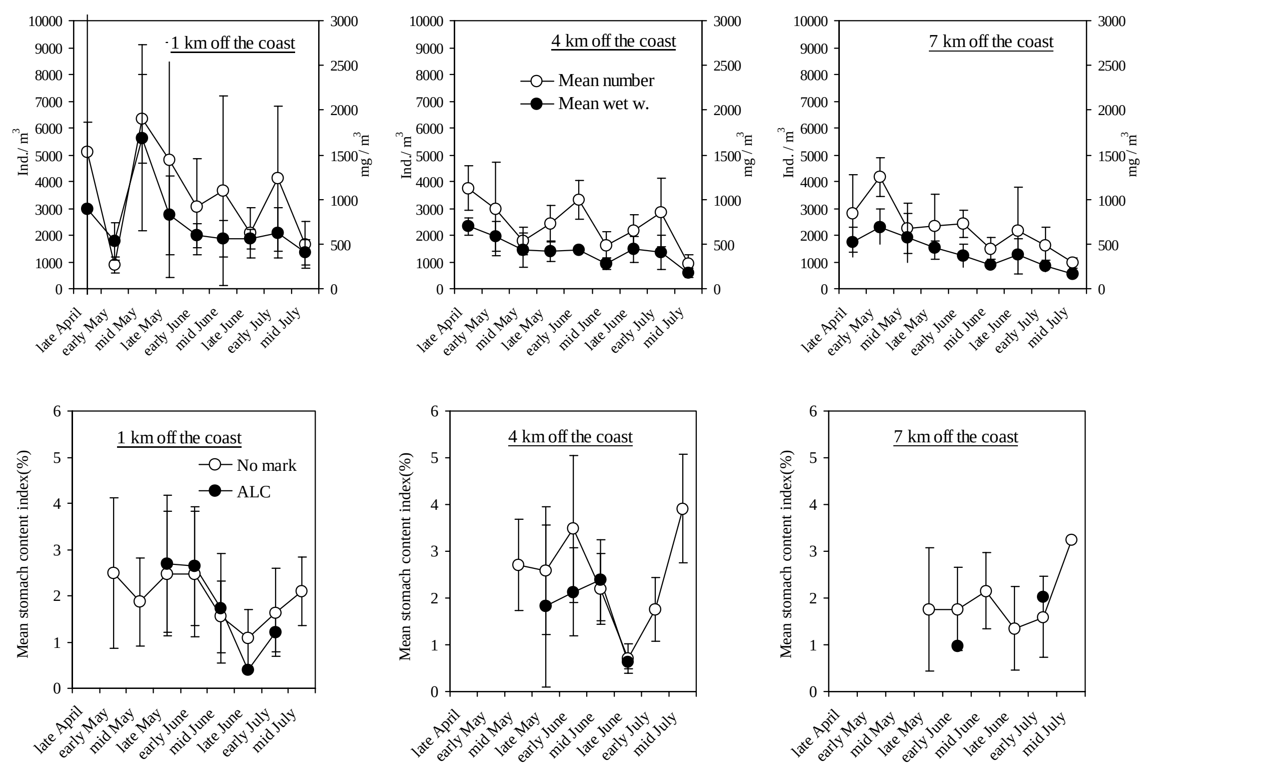


Fig. 4. Changes in mean values of zooplankton abundance, wet weight and stomach content index (stomach content weight x 100/body weight) of no-marked and ALC marked juvenile chum salmon captured at the 1km, 4km and 7km off the Abashiri coast in the Okhotsk Sea.



they moved offshore where SST > 14 °C (Irie, 1990). The 2002 year migration event showed the same pattern. Kaeriyama (1986 and 1989) found different types of offshore migration patterns for juvenile Japanese chum salmon. Early migrating juveniles tended to remain in the coastal waters with favorable conditions for a relatively long time where they grew fast, moving offshore later. In contrast, late migrating juveniles tended to remain nearshore for a short time because of unsuitable conditions such as a lack of food and high SST, subsequently they moved passively offshore. Our results also suggested that juvenile chum salmon that migrated early from the Abashiri River remained near shore and grew fast under the preferable conditions of abundant food and optimal SST (8–13 °C), and actively moved offshore afterwards. Later migrating juveniles may experience unfavorable conditions because of increases in fish density, decreases in prey abundance and high water temperatures, often exceeding 13 °C.

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