Geographical Origins of Juvenile Chum Salmon Migrating Along the Pacific Coast of Hokkaido, Japan, During Early Summer

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Japanese chum salmon migrate globally, from their natal river to the Gulf of Alaska via Okhotsk Sea, Northwest Pacific Ocean, and Bering Sea depending on their life stage and season (Urawa 2004; Urawa et al. 2018). Irie (1990) illustrated a map showing the migration route of juvenile chum salmon along the coastal waters of northern Japan, and the map was updated by Urawa et al. (2018). On the eastern Pacific coast of Hokkaido region (off Konbumori) there was a mixed community of juvenile chum salmon from the nearest and distinct rivers (Hasegawa et al. 2013), which was mainly composed of Pacific coast of Hokkaido and Honshu stocks (Sato et al. 2013). The present study was conducted to examine the origins of juvenile chum salmon migrating along the western and eastern Pacific coasts of Hokkaido by otolith marking and genetic stock identification analyses.

Juvenile chum salmon were captured at set nets in Muroran, Kojohama, Atsuga, and Harutachi coasts along the western Pacific coast of Hokkaido and at the four or five sampling stations (0.4–12 km offshore Konbumori) in the eastern Pacific coast of Hokkaido, during May to July of 2013–2016 (Fig. 1). Fish samples were collected by dip nets at the set nets and by a seine net towed by two boats at stations off Konbumori. Otolith and genetic samples were collected from each juvenile chum salmon after measurement of fork length (FL) and body weight. Otolith samples were examined for the presence of thermal marks and the hatchery origins were determined using specific thermal mark patterns. As for genetic samples, after DNA extraction, each sample was assayed for 45 single nucleotide polymorphism (SNP) loci using TaqMan chemistry (Sato et al. 2013). Five regional stock contributions (Hokkaido: Japan Sea coast, Okhotsk Sea/Nemuro Strait, and Pacific coast; Honshu: Pacific coast and Japan Sea coast) were estimated by a conditional maximum likelihood using a SNP baseline dataset from 57 populations (Sato et al. 2014) and an additional 24 populations (Sato et al. unpublished data). Furthermore, the weighted mean composition of five regional stocks was calculated in each survey area.

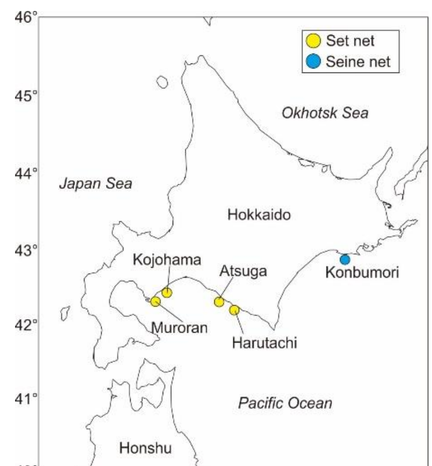

Fig. 1. Sampling locations of juvenile chum salmon along the Pacific coast of Hokkaido, Japan, during 2013–2016. Fish samples were collected at four or five stations (0.4–12 km from shore) in the Konbumori coast, but do not show detail in this figure.

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A total of 14,535 fish were collected in the Pacific coastal waters of Hokkaido in the spring and early summer of 2013–2016. The mean FL of juvenile chum salmon collected in Muroran and Kojohama coasts were 66.7±12.0 mm and 72.9±12.1 mm, respectively, while the mean FL of juvenile fish caught in Atsuga and Harutachi coasts were 96.1±52.2 mm and 93.1±11.2 mm, respectively. In Konbumori coast, the mean FL of juvenile chum salmon was 78.8±14.4 mm.

In the western Pacific coasts, 1,773 out of 12,098 juvenile chum salmon were otolith-marked fish, of which 1,639 juveniles (92.4%) originated from hatcheries along the western Pacific coast of Hokkaido, and 104 and one otolith-marked juvenile chum salmon were released from hatcheries along the eastern Pacific coast of Hokkaido and Nemuro Strait, respectively. In the Konbumori coast of eastern Pacific, 593 out of 2,437 samples (24.3%) were otolith-marked fish, of which 558 and 33 juveniles were released from hatcheries along the eastern and western Pacific coast of Hokkaido, respectively. Residual two otolith-marked chum salmon juvenile were originated from Oirase (Aomori Prefecture) and a hatchery in Iwate Prefecture along the Pacific coast of Honshu. A total of 31 otolith-marked juvenile chum salmon, which originated from hatcheries along the Pacific and Japan Sea coasts in Honshu, were collected from the all survey areas except the Muroran coast during 2013–2015 seasons. The mean FL of otolith-marked juvenile fish from Pacific and Japan Sea coasts of Honshu were 112.6±12.4 mm and 137.7±13.2 mm, respectively. Sixteen of the otolith-marked chum salmon juveniles originated from five hatcheries (Oirase, Orikasa, Shimoakka, Taro, and Tsugaruishi) along the Pacific coast of Honshu, while 11 other otolith-marked fish were released from hatcheries in Iwate Prefecture. Four otolith-marked fish originated from Oirase (Aomori Prefecture) and Kawabukuro (Akita Prefecture) hatcheries along the Japan Sea coast of Honshu. Twenty-four out of 31 otolith-marked juvenile fish from Honshu hatcheries (21 individuals from Pacific coast and three individuals from Japan Sea coast) were collected in Harutachi coast. No otolith-marked fish released from Honshu hatcheries were caught in 2016. The mean FL of otolith-marked fish originated from Hokkaido hatcheries was under 100 mm (Nemuro Strait: 94.6 mm, western Pacific coast: 87.3±17.4 mm, eastern Pacific coast: 75.7±8.7 mm), while that from Honshu hatcheries was significantly larger than Hokkaido fish (Tukey's test, $p < 0.05$).

The genetic stock identification suggested that the weighted mean stock compositions of small size fish (< 100 mm in FL) caught in all survey areas were 82.5–99.4% Hokkaido stocks (range: 2.1–11.1% Japan Sea coast, 18.2–26.5% Okhotsk Sea/Nemuro Strait, and 48.4–9.0% Pacific coast stocks) and 0.6–17.5% Honshu stocks (range: 0.6–5.7% Pacific coast and 0.0–11.8% Japan Sea coast). The Pacific coast Hokkaido stocks were most dominant in all survey areas. The weighted means of estimated stock composition of large size fish (≥100 mm in FL) collected in Kojohama, Atsuga, Harutachi, and Konbumori coasts were 57.7–71.6% Hokkaido stocks (range: 0.0–2.4% Japan Sea coast, 0.0–13.7% Okhotsk Sea/Nemuro Strait, and 41.5–71.6% Pacific coast stocks) and 28.4–42.3% Honshu stocks (range: 8.6–32.0% Pacific coast and 0.6–20.7% Japan Sea coast stocks). In the 2016 season, however, the proportion of Pacific and Japan Sea coasts of Honshu stocks were 7.8–17.0% and 0.0–8.0% in Harutachi and Konbumori coasts, respectively.

Otolith-marked juvenile chum salmon released from hatcheries along the western Pacific coast in Hokkaido were the most dominant in the western Pacific coast in Hokkaido. In addition, several otolith-marked juvenile fish originating from the eastern Pacific coast in Hokkaido were collected at the same areas. A previous study also demonstrated that juvenile chum salmon of the eastern Pacific coast of Hokkaido stocks (Tokachi and Kushiro rivers) migrated westward to the western Pacific coast in Hokkaido (Saito et al. 2013).

The present study confirmed that otolith-marked fish released from the Pacific and Japan Sea coasts in Honshu were present along the western Pacific coast in Hokkaido. Particularly, most of the Pacific coast Honshu stocks were collected in Hidaka (Harutachi). These findings suggest that juvenile chum salmon that originated from the Pacific coast of Honshu may reach the western Pacific coast (Hidaka coast) and then migrate west or eastward along the Pacific coast in Hokkaido. In addition, some juvenile chum salmon originating from the Japan Sea coast of Honshu also migrate along the Pacific coast of Hokkaido through the Tugaru Strait. These migration routes were also simulated by a hydrodynamic model (Azumaya et al. in press).

Our results indicated that the mean FL of otolith-marked juvenile chum salmon from Honshu was significantly higher than that of the Hokkaido stocks. The genetic stock identification also suggests the composition of the Pacific coast of Honshu stocks was relatively higher in the large juvenile chum salmon group (FL ≥ 100 mm) than the small fish group (FL < 100 mm). A previous study indicated that juvenile chum salmon migrating from distant rivers with achievement of a certain growth rate had better survival and were able to arrive the eastern Pacific coast in Hokkaido (Honda et al. 2017). The present results may support this hypothesis.

No otolith-marked fish released from Honshu hatcheries were caught in 2016. Stock composition of juvenile chum salmon originated from the Pacific coast of Honshu in 2016 was also lower than that of 2013–2015 seasons. During early-May to late-June in 2016, the surface seawater temperature (SST) anomalies of Pacific coast around

Hokkaido and Honshu indicated were approximately 2–5ºC higher (data source: Japan Meteorological Agency, www.jma.go.jp/jma/index.html). This unfavorable ocean condition might affect the migration and survival of juvenile fish in 2016.

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