Using Genetic Markers to Understand the Coastal Migration of Juvenile Coho (*Oncorhynchus kisutch*) and Chinook Salmon (*O. tshawytscha*)

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The production of salmon has been shown to vary in relation to climate and ocean conditions at small and large spatial scales (Beamish et al. 1999; Hare et al. 1999; Welch et al. 2000; Mueter et al. 2002). Hence, the fate of individual salmon stocks may depend on where they migrate to in the ocean, and the amount of time they spend in different regions of the ocean.

The ocean migration of juvenile salmon has generally been studied using coded-wire tags (CWT) (Percy and Fisher 1988; Fisher and Pearcy 1995; Orsi and Jaenicke 1996; Orsi et al. 2000) and thermally marked otoliths (Carlson et al. 2000). Although the determination of the origin of CWT and thermally marked fish is unequivocal, these approaches may not reflect the stock composition of salmon in a given area as only a fraction of the fish are marked. The development of molecular techniques has enabled fisheries scientists to accurately assess the origin of ocean caught fish (Beacham et al. 2003a; Hallerman 2003). Hence, genetic markers could be a useful tool for assessing the migration routes of juvenile salmon at sea (Teel et al. 2003).

The objectives of this study were to determine the ocean distribution and migration of juvenile chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) along the west coast of British Columbia (BC) and Southeastern Alaska (SEA) using genetic markers. We also compared stock composition estimates derived using CWT and genetic markers.

Juvenile chinook and coho salmon were collected on the west coast of BC and SE Alaska during the summer and fall of 1998–2002 and winter 2001–2002. A mid-water rope trawl (ca. 90 m long X 30 m wide X 15 m deep; cod-end mesh 0.6 cm; Cantrawl Pacific Ltd., Richmond, BC) was hauled at the surface (0–20 m) for 15–30 minutes at 5 knots using the R/V *W.E. Ricker*. Sampling was conducted between 06:00 and 18:00 (Pacific Time). Up to 30 juvenile salmon of each species were randomly selected from each net tow. Fork length and mass were determined on board the research vessel using a ruler and an electronic scale equipped with a counterweight to correct for ship motion. Otoliths and scales were removed from these fish for age determination. A tissue sample was also taken from the operculum using a hole punch and preserved in 70% ethanol for stock identification. All the fish were scanned with a metal detector to determine the presence of CWT.

Juvenile chinook salmon were surveyed for 13 microsatellite loci (MSL) and coho were surveyed for 2 major histocompatibility complex (MHC) and 4–8 MSL (some of the early data in 1998 and 1999 were surveyed for 2 MHC and 4 MSL) (Small et al. 1998a, b; Beacham et al. 2003a, b). Using a maximum likelihood method (MLE), individuals of unknown origin were compared to coast-wide genetic baselines consisting of ca. 44,000 individuals representing over 240 populations from California to Alaska. The MLE model assigned the mixture composition to individual populations which were then summed into regional groupings for three seasons: summer (May–August), fall (September–November), and end-of-winter (February–March). Further details on the mixed-stock analyses used in this study can be obtained from Small et al. (1998a, b) and Beacham et al. (2003a, b).

A total of 2,529 juvenile salmon was analysed in this study for MSL and MHC. Columbia River (CR) chinook salmon represented approximately 50% of the juvenile chinook caught in BC and Alaska shelf waters during summer, but constituted less than 10% of the samples caught during fall and end-of-winter (Table 1). Spring chinook from the Upper CR and Snake River represented 31% and 39%, respectively, of the CR chinook. In the fall and end-of-winter samples, juvenile chinook salmon collected in Southern BC and SEA originated mostly from the west coast of Vancouver Island (WCVI) and central coast region of BC, respectively (Table 1). Stock composition of chinook salmon in both regions remained fairly constant over the winter (Table 1), suggesting that by autumn chinook had established stable residence in these areas. One notable difference, however, was that the proportion of Strait of Georgia or Puget Sound stocks consistently increased off the WCVI while WCVI stocks decreased, suggesting an influx of Georgia Basin to the west coast of Vancouver Island over the winter months.

CR coho salmon represented up to 25% of the juvenile coho caught in southern BC during summer (Table 2). They constituted less than 5% of the coho salmon caught during fall and winter and negligible proportions of the coho in the northern region (Table 2). Overwinter stock composition of coho salmon in southern BC coastal waters was also reasonably stable, suggesting that most stocks of coho established stable residence in this area, but that

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there was an influx of coastal BC coho and a decline in WCVI coho abundance (Table 2). It is unclear where northern stocks moved to over the winter months. Juvenile coho salmon were absent from northern BC and SEA coastal waters by the end of winter. Coho resident in this area likely migrated north on the continental shelf or due west directly into the open waters of the Gulf of Alaska, as the proportion of the northern stocks did not increase on the west coast of Vancouver Island during winter (Table 2).

Ten percent of the juvenile salmon examined in this study were marked with CWT. Although the presence of CR chinook and coho in BC and SEA was confirmed by CWT, CWT stock composition did not agree with DNA-derived estimates. CWT indicated that Alaska and CR chinook represented 65% and 27% of the juvenile chinook caught in SEA. In contrast, DNA analyses indicated that Alaska chinook represented less than 10% of the chinook caught in SEA. Similarly, CWT indicated that 78% and 16% of the juvenile chinook salmon originated from the CR

Table 1. Stock composition (%) of juvenile chinook salmon (< 350 mm FL) caught in southern British Columbia (49–51°N) and southeastern Alaska (54–58°N) in 1998–2002 determined using microsatellite DNA. SE Alaska: Southeastern Alaska; Coastal B.C. Coastal British Columbia; ECVI: East coast of Vancouver Island; WVCI: West coast of Vancouver Island.

	Southern BC			Northern BC – SE Alaska		
	Summer	Fall	Winter	Summer	Fall	Winter
	n=350	n=345	n=255	n=113	n=176	n=165
SE Alaska	0.8	0.3	0.0	1.7	5.8	5.4
Coastal B.C.	5.2	11.8	4.0	11.9	84.2	82.5
Skeena/Nass	1.8	0.2	0.0	5.8	6.5	10.8
Fraser	17.8	3.4	11.2	11.0	0.5	1.1
ECVI	2.2	0.2	2.3	7.0	0.7	0.0
WCVI	5.3	77.1	65.1	7.4	0.5	0.6
Puget Sound	8.0	0.7	9.0	4.6	0.0	0.0
Coastal Wash	4.2	0.0	3.3	5.6	0.2	0.0
Columbia	53.1	4.9	4.9	40.8	1.8	0.0
Oregon	0.8	0.6	0.0	4.3	0.0	0.0
California	0.8	0.3	0.0	0.0	0.0	0.0

Table 2. Stock composition (%) of juvenile coho salmon caught in southern British Columbia (49–51°N) and southeastern Alaska (54–58°N) in 1998–2002 determined using microsatellite DNA and major histocompatibility complex. SE Alaska: Southeastern Alaska; Coastal B.C. Coastal British Columbia; ECVI: East coast of Vancouver Island; WVCI: West coast of Vancouver Island.

	Southern BC			Northern BC – SE Alaska		
	Summer	Fall	Winter	Summer	Fall	Winter
	n=440	n=169	n=227	n=113	n=176	n=0
SE Alaska	1.8	3.4	0.6	20.7	12.2	--
Coastal B.C.	12.8	22.4	37.6	30.3	26.1	--
Skeena/Nass	2.0	7.4	6.3	17.5	31.8	--
Fraser	4.8	5.8	12.5	3.5	6.9	--
ECVI	13.0	23.2	18.8	5.6	6.7	--
WCVI	11.8	23.5	10.2	8.1	8.9	--
Puget Sound	9.7	3.8	9.2	3.9	3.9	--
Coastal US	18.0	8.5	7.9	7.3	2.8	--
Columbia	25.7	2.0	1.9	1.9	0.8	--
California	0.5	0.0	0.0	1.3	0.4	--

and BC in southern BC. DNA analyses indicated that CR chinook represented at most 40% of the chinook caught in southern BC during summer, but then declined to less than 5% thereafter, while BC chinook represented over 70% of the chinook caught during fall and winter in this region. Similar results were also observed for juvenile coho salmon. The discrepancy between stock composition estimates obtained with DNA and CWT may be attributed to the low recoveries of CWT in our samples, and to the limited number of populations of salmon are marked with CWT.

In summary, our analyses indicate that there are clear stock-specific differences in the migratory behaviour of chinook and coho salmon. Thus, individual stocks will be affected differently by climate depending on the biological and physical conditions encountered during their ocean life.

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