Potential Interrelationships between Patterns of Migration and Marine Survival in Pacific Salmon

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There is a 10-fold difference in coho marine survival between different regions of the West Coast of North America. Survival is lowest in the south (Washington-Oregon) and highest in the north (Alaska). Salmon swimming through regions of different survival should have different fates, with the poorest-performing stocks spending the longest period in areas of poor survival, and the best-performing stocks spending the least amount of time in these areas. Permanent shelf-resident stocks would presumably have the worst productivity of all. However, the migration route and foraging grounds of most stocks of Pacific salmon are not well known.

We conducted multiple ocean surveys each year since 1995 to examine ocean growth, migration patterns, and expected survival of juvenile salmon along the West Coast from southern Vancouver Island to the Aleutians. The results show that juvenile salmon appear to remain strictly on the continental shelf until at least the start of winter, and that stocks migrating to the offshore do so by first swimming along the shelf to the Aleutian Islands before eventually moving offshore (Fig. 1). Figure 2 (A) shows a close-up view of the composite salmon catches (all species) from all October surveys off the West Coast (British Columbia to South East Alaska). Figure 2 (B) shows the distribution off the Alaska Peninsula in November–December 1997. These results indicate that juveniles were still on the continental shelf in early winter all the way to the Aleutians. Note the long multi-day transect moving in towards Kodiak from the offshore, and the abrupt occurrence of juvenile salmon in the catches at the shelf edge. This transect was made in late November, long after the juveniles were originally suggested to leave the shelf (Hartt and Dell 1986).

Large numbers of tagged juvenile salmon (all species) released from hatcheries (▲) have been caught on our surveys (●). These animals all moved north and west along the continental shelf (Fig 3). Although we have shown the great circle (minimum distance) lines connecting river mouths to recovery sites, the distributional studies demonstrate that the salmon must have navigated to remain strictly over the continental shelf despite this not being the shortest migration path.

Captures of CWT & PIT-tagged chinook and coho allow us to calculate migration rates (Fig. 4). Salmon caught in the summer exhibit a wide range of swimming speeds, with some moving at up to 2 body lengths/sec for months. By autumn (lower panels), migration rates are much slower, reflecting the fact that rapidly moving juveniles have travelled thousands of kilometers over the summer, and are thus no longer present in our study area. This suggest that there are at least two specific migration behaviours evident, with the slow speeds for fall-caught fish suggesting that these are animals taking up shelf-residence in particular areas of the shelf. This would expose them to different ocean conditions in different regions of the shelf (See Trudel et al. this volume).

Our research indicates that juvenile salmon undertake rapid long-distance migrations that are highly directed to maintain them over the continental shelf.

Fig. 1. Distribution of all positive juvenile salmon catches (•) from fall sampling efforts (1995 to present). Locations where no salmon were caught are indicated by a cross (x). The results show that juvenile salmon remain within the shelf ecosystem much longer than previously suspected. The black line shows the position of the shelf edge (1,000 m isobath). Note that no salmon were caught off the shelf.

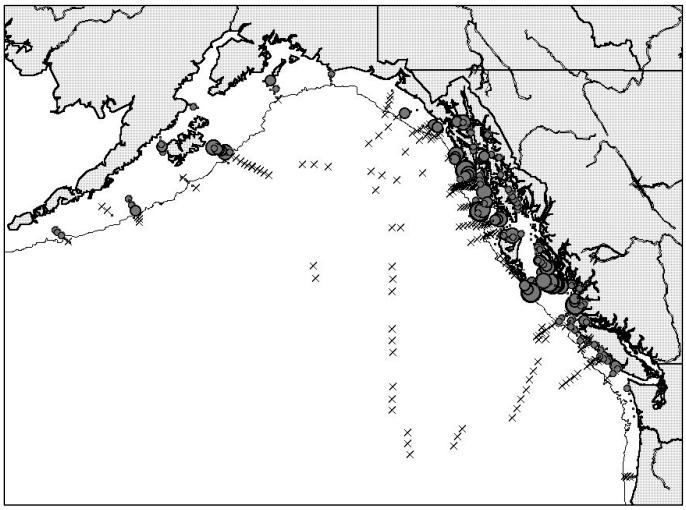

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Fig. 2. Distribution of juvenile salmon (all species combined) from Autumn and early Winter surveys, all years combined. (A) Juvenile salmon catches from all October surveys combined along the British Columbia and SE Alaska coastal zones. The 1,000 m isobath, delimiting the shelf break, is indicated. Note that all salmon catches were confined to the continental shelf. (B). A similar example but concentrating on a single early winter cruise to south of the Alaska Peninsula in early winter. Note the abrupt reoccurrence of juvenile salmon once the shelf break is reached SE of Kodiak Island (end of November). The subsequent survey lines in early December found no evidence for juvenile salmon leaving the shelf except on the far west survey line on December 7th, when 10% of the salmon catch was caught off shelf. The December 7th sampling is the only significant evidence we have obtained for off-shelf distribution of juvenile Pacific salmon, suggesting that most salmon stocks migrate along the shelf to the Aleutian Islands before moving to the offshore (See Fig. 3).

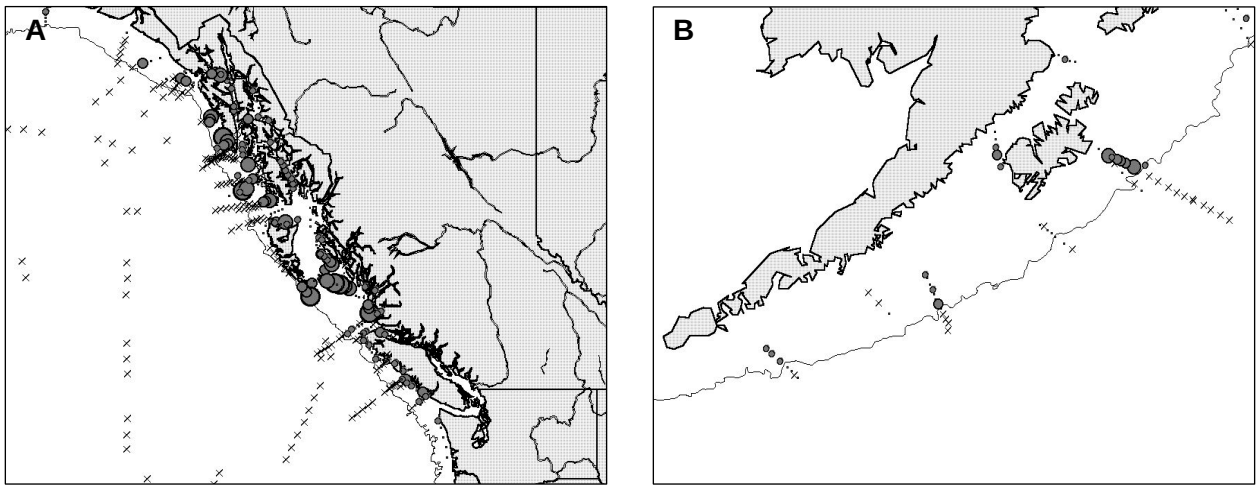


Fig. 3. Examples of long-distance recoveries of tagged Pacific salmon. Note the significant movements of some animals; chinook from the Sacramento Valley, California, have been caught off British Columbia, as have substantial numbers of endangered Snake R. chinook. Migration speeds for the Snake River chinook are the fastest we have recorded to date (>2BL/sec; see below). Great circle routes are drawn to show the relationship between release and recovery positions, but as the distribution of juvenile salmon catches makes clear, the animals do not leave the shelf ecosystem and must have therefore taken a migration path that maintained them over the continental shelf. The results suggest that juvenile coho may undertake larger-scale movements than chinook, since coho were caught farther away from their home streams, yet both species were caught on the same surveys.

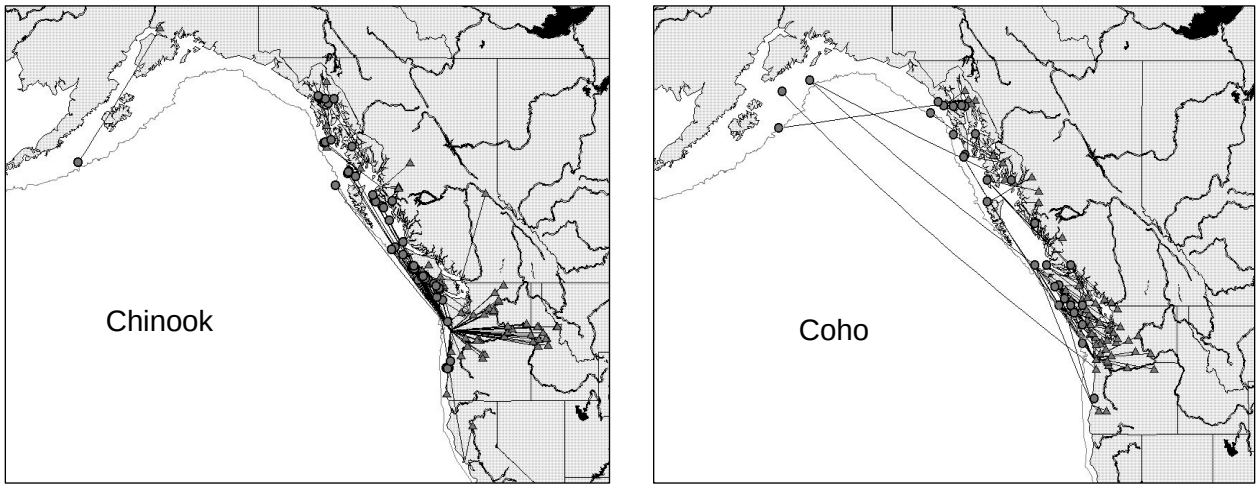
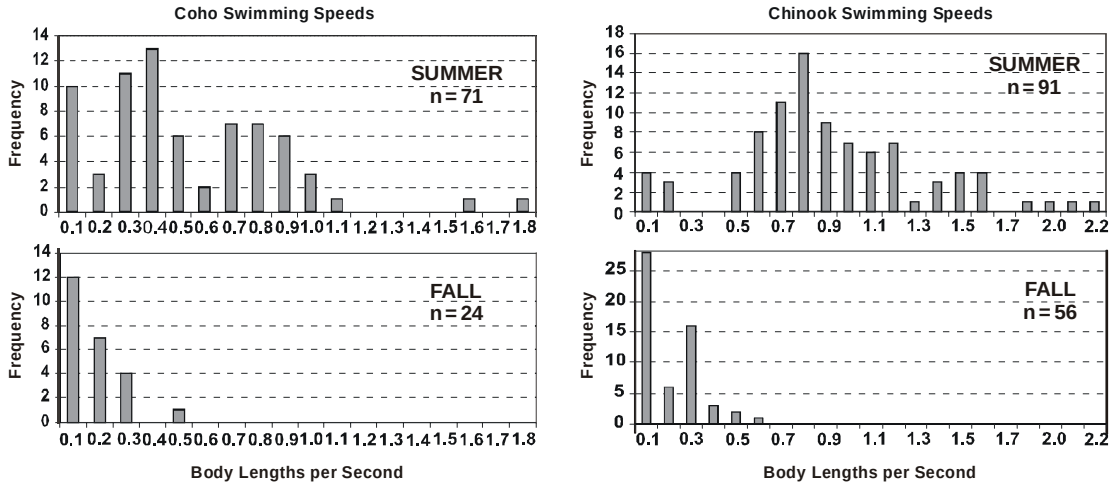


Fig. 4. Comparison of coho and chinook salmon swimming speeds, calculated from all CWT or PIT-tagged salmon returns (1995–2001). The top row shows the minimum possible swimming speed, calculated on the assumption that each animal remained over the shelf but followed the shortest shelf-bound path to the capture location.



There is evidence from tag recoveries that some coho and chinook move rapidly to the Aleutians, while we speculate that specific stocks remain in the coastal zone as long-term over-winter residents. These patterns of movement, interacting with regional differences in climate-induced carrying capacity, may explain the peculiar patterns of salmon productivity along the West Coast of North America that have been observed in recent years.

Our conclusions are based on the overall distribution of juvenile salmon catches relative to the shelf edge, and the observation that tagged hatchery smolts can in relatively short time periods move long distances before capture. Details of the movement patterns of individual animals in between the release and recovery positions are needed to address questions concerning possible stock-specific patterns of behaviour. A critical issue will be to develop methods to track the migration of individual stocks of salmon, and to then develop a predictive understanding of which stock groupings may be influenced most significantly by shifts in ocean climate. Because the continental shelf off the West Coast of North America is so narrow relative to its length (only 30–40 kms wide relative to a 4,000 km long migration path), this raises the possibility of developing an acoustic tracking array consisting of multiple cross-shelf listening lines. Such an array could provide a wealth of detail concerning the movement patterns of individual salmon over many months or years on the continental shelf.

REFERENCES

Hartt, A.C., and M.B. Dell. 1986. Early Oceanic Migrations and Growth of Juvenile Pacific Salmon and Steelhead Trout. Int. North Pac. Fish. Comm. Bull. No. 46: 1–105.

Trudel, M., S. Tucker, J.E. Zamon, J.F.T. Morris, D.A. Higgs, and D.W. Welch. This volume. Bioenergetic response of coho salmon to climate change. N. Pac. Anadr. Fish Comm. Tech. Rep. No. 4.