Life History Diversity, Marine Survival, and Viability of Pacific Salmon

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The hypothesis that ocean productivity to support salmon populations fluctuates between "good" and "bad" cycles that can span 2–3 decades, and that these fluctuations are negatively correlated between waters off Alaska and the Pacific Northwest, is gaining increasing acceptance. However, not all populations within a geographic area respond to common environmental conditions in the same way. Genetic and life history diversity among salmon and steelhead populations leads to considerable variability in their response to the marine environment. Conversely, events that occur during the marine phase of the life cycle can profoundly affect metapopulation structure and diversity of salmon and steelhead populations in fresh water. Some empirical examples illustrate that these patterns of genetic and life history diversity can be important on a variety of spatial and temporal scales.

Figure 1 shows the timing of arrival at a mainstem Snake River dam of outmigrating chinook salmon (*Oncorhynchus tshawytscha*) smolts that had been implanted with Passive Integrated Responder tags (PIT tags) as wild parr or as presmolts in hatcheries (Achord et al. 1996). The natural populations show a protracted outmigration timing over a more than 3-month period that reflects diversity within populations as well as differences among populations in mean outmigration timing. In contrast, hatchery smolts are typically released during a short temporal window in early spring. More recent research (J. Williams, Northwest Fisheries Science Center, personal communication) has shown that just a few days difference in date of ocean entry of spring/summer chinook salmon smolts collected at mainstem Columbia and Snake River dams and barged to the estuary can result in a 5- or 10-fold difference in marine survival rate. Similarly, recent genetic studies of juvenile chinook salmon during their first critical summer at sea show that stock composition of juveniles in nearshore waters changes dramatically during the course of the season (D. Teel, Northwest Fisheries Science Center, personal communication).

Snake River spring/summer chinook salmon, together with spring chinook from the mid and upper Columbia, are part of what is referred to as the stream-type lineage (Healey 1991; Myers et al. 1998); the ocean-type lineage includes other Columbia River and all coastal populations. Little is known of the ocean ecology of stream-type chinook salmon except that they are only rarely taken in continental shelf fisheries that typically harvest ocean-type populations at relatively high rates. Presumably, therefore, Columbia River stream-type chinook salmon utilize the marine environment in a very different way than do ocean-type populations, either moving off the continental shelf during times the ocean-type populations are vulnerable to harvest, or adopting behavioral patterns that make them less susceptible to harvest. This fundamental difference in utilization of the marine environment is associated with a deep evolutionary split and is not affected by environmental factors that may alter smolt age or migration or spawn timing (Myers et al. 1998). If the stream-type chinook salmon lineage was lost in the interior Columbia River basin, it is possible that spring-run fish would re-evolve from summer or fall chinook in the ocean-type lineage (a scenario that has occurred

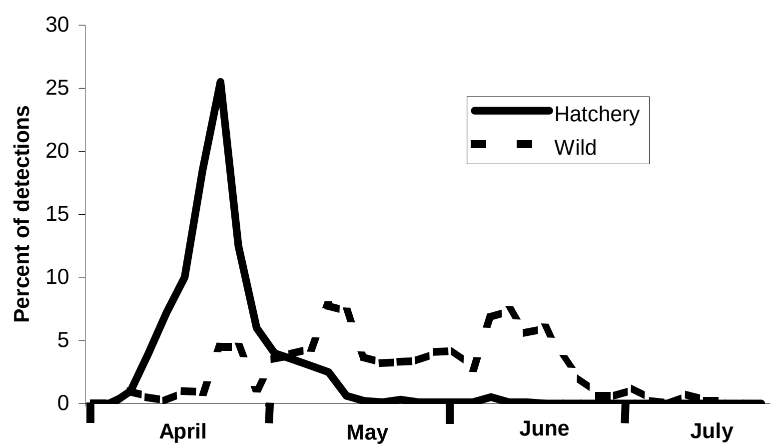

Fig. 1. Detection of PIT-tagged juvenile Snake River spring/summer chinook salmon as they migrated though Lower Granite Dam in 1989. Wild fish were tagged as parr in late summer 1988 from streams in the Salmon, Imnaha, Grande Ronde, and Clearwater river basins; hatchery fish were tagged before release in spring 1989 at Lookingglass and Sawtooth Hatcheries. Percentages of total detections are plotted separately for hatchery and wild groups as sums over 3-day periods. Modified from Achord et al. (1996).

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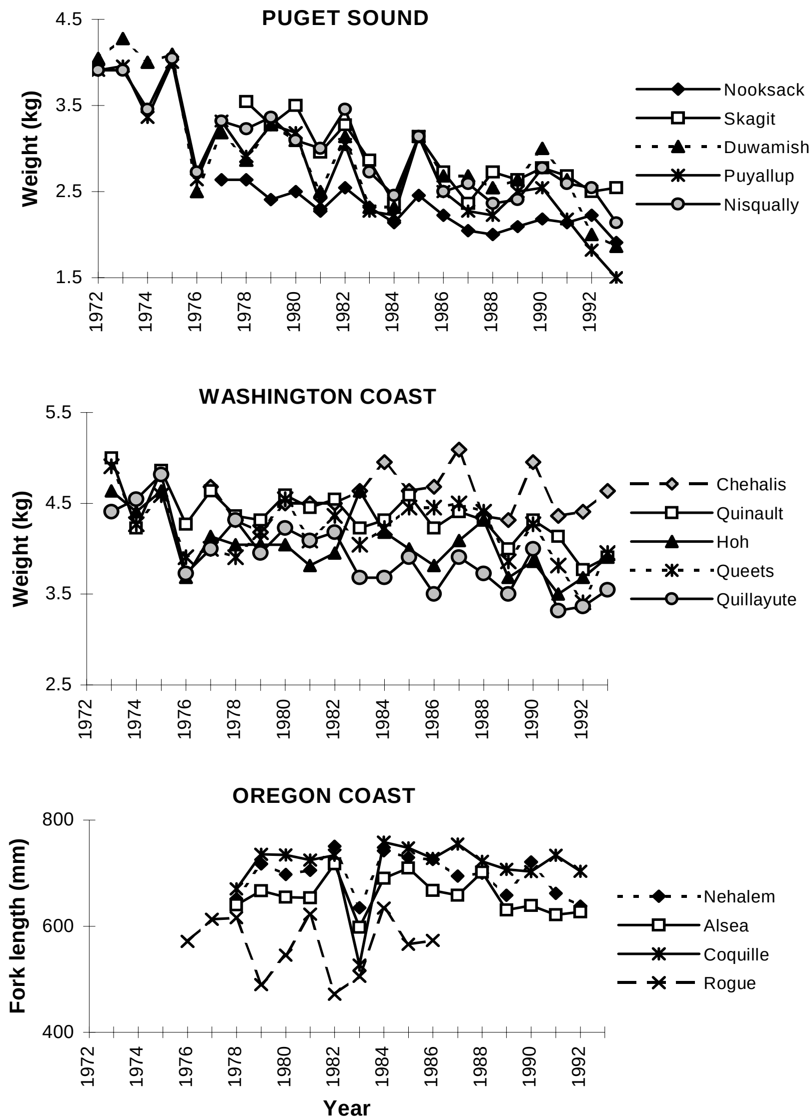
repeatedly in coastal basins), although it likely would take a long time from the human perspective for this to occur. Even if it did occur, however, the resulting spring-run fish might not be yearling migrants, and there is no reason to expect that they would adopt the marine ecological patterns of the extirpated stream-type lineage. The result would be a profound (and long lasting) loss of diversity and overall productivity within the basin.

Figure 2, which shows patterns of variation in adult size of coho salmon (*O. kisutch*) over a 20-year period, provides evidence of geographic differences in marine ecology in this species as well (Weitkamp et al. 1997). A pronounced and steady decline in adult size was seen in Puget Sound, but not coastal populations. Although possible explanations for this pattern are numerous, human factors such as size-selective fisheries, genetic changes in hatcheries, and freshwater condition factor could differentially affect marine growth and survival of coho salmon. Second, the response to the large 1982–83 El Niño event was different in populations from the three areas. Oregon coast coho populations showed a pronounced reduction in adult size in 1983, but a similar reduction was not seen in populations from the Washington coast. Puget Sound also showed a sharp reduction in size, but the effect was greatest in 1984 rather than 1983. Although freshwater effects on adult size cannot be entirely ruled out, the most plausible explanation for these data is that populations from the three geographic areas utilize the ocean environment in different ways. Populations from the Washington coast apparently avoided most of the deleterious effects of El Niño experienced by the Oregon coast populations. The phenotypic effects of the El Niño were delayed a year in Puget Sound coho salmon, suggesting that either (a) the El Niño affected coho in their first year at sea in Puget Sound and their second year at sea in Oregon, or (b) the effects of El Niño persisted for an additional year in marine waters occupied by Puget Sound fish.

Fig. 2. Variation in adult size (weight measured in in-river fisheries or length of natural spawners) of coho salmon from Puget Sound and the Oregon and Washington coasts, 1972–1993. Source: Weitkamp et al. (1997).



Collectively, these data demonstrate that interactions between life history, genetic, and ecological diversity of salmon populations and their freshwater and marine environments can profoundly affect their population dynamics and sustainability. For example, the wide diversity in outmigration timing and early marine life history that has evolved in Snake River chinook salmon provides a substantial buffer against fine-scale temporal changes in freshwater and marine risk factors. A variety of anthropogenic factors, including impediments to migration, instream flow management, harvest, and hatchery releases, can affect these life history traits and survival in both terrestrial and marine habitats. Effective recovery planning must recognize these complex relationships.

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