How Related are Environmental Sources of Variation for British Columbia and Alaska Sockeye Salmon?

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Pacific salmon populations (*Oncorhynchus* spp.) show considerable variation over time in survival rates, growth rates, and age at maturity. To better manage these stocks, it is necessary to understand the spatial extent and temporal patterns of environmentally-driven variability in these components of recruitment. We used a multi-stock comparison to identify these spatial and temporal characteristics of variability. The data we used span four decades (late 1940s to mid-1990s) for 29 sockeye salmon (*O. nerka*) stocks from a wide geographical area across British Columbia and Alaska: 16 Fraser River stocks (southern B.C.), the Skeena and Nass River stocks (central B.C.), the Copper River and Cook Inlet stocks (central Alaska), and 9 Bristol Bay stocks (western Alaska). The distributions of stocks from these various regions overlap for much of their marine life.

Specifically, we examined patterns of covariation among these stocks using annual indices of (i) survival rate (residuals from the best-fit stock-recruitment curve), (ii) growth rate (body size at a given adult age), and (iii) mean age at maturity. For each of these components of recruitment, correlation coefficients were calculated for pairwise comparisons among stocks. In addition, we computed correlations among the marine and freshwater survival-rate indices of 6 stocks for which smolt abundance data were available -- the Chilko (Fraser R.), Skeena River, and 4 Bristol Bay stocks. For indices of body size and mean-age, we used principal components analysis (PCA) to further identify the common components of variability among stocks.

For indices of survival rate, we found strong positive covariation among survival-rate indices of the 9 Bristol Bay stocks (all 36 correlations were positive; average $r = 0.45$). There was weaker but predominantly positive covariation among the 16 Fraser River sockeye stocks (94 of the 120 correlations were positive; average $r = 0.15$). However, there was no evidence of positive covariation between Fraser River and Bristol Bay stocks (average $r = -0.05$) or with stocks of other regions in B.C. and Alaska. These results suggest that within each region (i.e., Fraser River or Bristol Bay), the interannual variability of survival rates of sockeye stocks is influenced by common environmental processes, but that these processes are distinct for each of these two regions. Furthermore, analyses of freshwater and marine survival-rate indices indicated that the observed covariation in survival rates of Bristol Bay stocks was due to a combination of freshwater and, to a greater extent, marine processes, whereas marine processes may be most important for Fraser River stocks.

Patterns of covariation among survival rates of Fraser River and Bristol Bay stocks have also been examined by fitting different types of models that include environmental effects to stock-recruit data (details given in Adkison et al. 1996). For the 9 Bristol Bay stocks, the best-fit model was a one-time shift in parameters of the Ricker stock-recruitment curve, coinciding with the rapid change in the mid-1970s in intensity of the Aleutian low-pressure weather systems and associated wind-driven processes (Hare and Francis 1995). On average, the Ricker 'a' parameter (an index of productivity) of these stocks increased 3-fold between the early and late 1970s, whereas the Ricker 'b' parameter did not change appreciably or consistently among stocks. This dramatic increase in productivity is consistent with Brodeur and Ware's (1992) finding that zooplankton abundance increased

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between those two periods in the Gulf of Alaska. In contrast, the 12 Fraser River sockeye stocks examined in this analysis did not show a consistent change in either 'a' or 'b' parameters over this same period. This result is consistent with our findings that environmental processes causing covariation among survival rates of Fraser River sockeye salmon differ from those processes affecting Bristol Bay sockeye salmon, and suggests that only the latter were strongly influenced by the mid-1970s climate shift.

In contrast, for the index of growth rate, we found widespread positive covariation across all ages and stocks from B.C. and Alaska (2,345 of the 2,556 correlations were positive; average $r = 0.37$), indicating that both regional and ocean-basin scale processes were important determinants of adult body size. The dominant principal component for body size, which accounted for 58% of the total variation, had a significant decreasing time trend ($P<0.001$) over the period 1971 to 1994.

Indices of age at maturity also showed both regional and ocean-basin scale covariation, although the covariation was weaker (397 of the 496 correlations were positive; average $r = 0.17$). In contrast to the body-size data, the dominant principal component (accounting for 35% of the total variation) for mean age had a significant increasing time trend ($P<0.001$) from 1971 to 1990. These patterns of covariation and time trends in mean age and body size of B.C. and Alaska sockeye salmon may be related to physical oceanographic variables (Cox and Hinch 1997) and ocean abundance of salmon (Bigler et al. 1995). Further details will be published elsewhere.

REFERENCES

Adkison, M.D., R.M. Peterman, M.F. Lapointe, D.M. Gillis, and J. Korman. 1996. Alternative models of climatic effects on sockeye salmon (*Oncorhynchus nerka*) production in Bristol Bay, Alaska, and the Fraser River, British Columbia. Fisheries Oceanography 5:137-152.

Bigler, B.S., D.W. Welch, and J.H. Helle. 1996. A review of size trends among North Pacific salmon (*Oncorhynchus* spp.). Can. J. Fish. Aquat. Sci. 53:455-465.

Brodeur, R.D., and D.M. Ware. 1992. Interannual and interdecadal changes in zooplankton biomass in the subarctic Pacific Ocean. Fisheries Oceanography 1:32-38.

Cox, S.P., and S.G. Hinch. Changes in size at maturity of Fraser River sockeye salmon (*Oncorhynchus nerka*) (1952-1993) and associations with temperature. Can. J. Fish. Aquat. Sci. 54:1159-1165.

Hare, S.R., and Francis, R.C. 1995. Climate change and salmon production in the northeast Pacific Ocean, p. 357-372. *In* R. J. Beamish (ed.), Climate Change and Northern Fish Populations. Can. Spec. Publ. Fish. Aquat. Sci. 121.