Abiotic and Biotic Factors Influencing Food Habits of Pacific Salmon in the Gulf of Alaska

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Keywords: Pacific salmon, food contents, high seas, salmon feeding, diet diversity, carrying capacity, density dependence, Gulf of Alaska, Alaskan Gyre, gonatid squid, seamounts, bioenergetics

A major difficulty in assessing feeding competition, and thus quantifying density-dependent growth and the carrying capacity of Pacific Salmon in the North Pacific Ocean, arises from the large amount of variability in high-seas foraging conditions, both within and between years. Differences in prey populations, prey patchiness, seawater temperature, and other oceanographic conditions all conspire to mask the relationship between salmon density and food. In addition, "salmon density" as measured by catch per unit effort (CPUE) does not represent uniform competition, as salmon may differ in their food preferences depending on species, size, age, or maturity condition.

In this study, I analyzed the food habits of salmon collected on the research vessel *Oshoro maru* along a 145°W transect line, between 50° and 56°N, in July 1994-97. In addition, I examined data collected over the oceanic seamounts at 143-147°W, 55-57°N, in the 1980s and 1990s. Using generalized additive models (GAM), generalized linear models (GLM), and graphical analysis of stomach contents data, I show the contribution of some biotic and abiotic factors to feeding variability in pink, chum, sockeye, and coho salmon. The results of these analyses reveal some of the interplay between sea surface temperature, oceanographic conditions, salmon size and maturity, catch rates, and interannual changes in salmon prey.

Along the 145°W transect line in the 1990s, CPUE data indicate that pink and coho salmon show low interannual variability in July distribution, increasing in density from south to north. Sockeye and chum salmon also increase in density from south to north, but show a southerly peak of distribution in 1994 and 1996 at local temperature minima. This peak may be due to salmon clustering around temperature minima, increased catchability at minima, or salmon aggregation at the oceanographic transition between the Subarctic Current and the Ridge Domain. The southerly limit of salmon distribution does not correspond with a precise temperature minimum.

Feeding along the transect line is divided into two zones, the southerly zone being a region of high squid consumption for pink, coho, and sockeye salmon, and the northerly zone having high crustacean zooplankton consumption for pink and sockeye salmon. Chum salmon primarily consume gelatinous zooplankton in both zones. The divide between these two zones varies by species and year; for example, in 1996 coho consume squid along the entire transect line.

Examination of interannual variability over the seamount area reveals similar stomach content indices (SCI=(prey weight* 10^6)/(salmon body weight)) values for all species in the 1990s, regardless of prey species consumed. The one exception is in 1996, in which coho salmon have an extremely high SCI due to the extension of squid into northern regions (Fig. 1). In addition, pink salmon have a significant odd/even cycle in SCI due to euphasiids, with high euphasiid catches in odd years. This differs from the southern region, where pink salmon have significantly higher squid consumption in even years. SCI increases with temperature for all species, although the highest temperature ranges are found only in 1997.

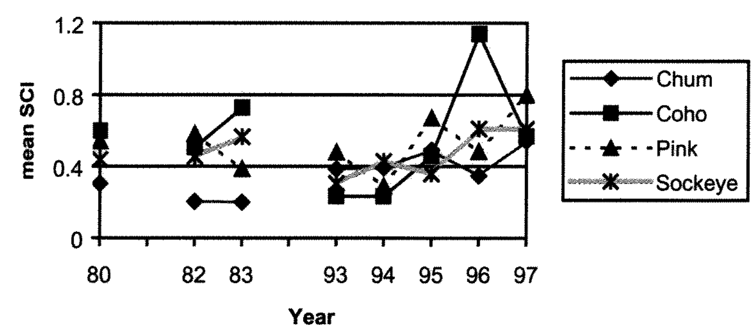

Fig. 1. Mean SCI (prey weight*10^6/body weight) of four salmon species in the seamount area (143-147°W, 55-57°N).

Examining SCI variation by individual body weight of salmon reveals differences between salmon species. Chum salmon show a constant volume of food as body weight increases, possibly due to constraints of feeding on gelatinous zooplankton. Coho salmon eat an increasing percentage of body weight per day, perhaps due to an increasing ability to catch squid. Sockeye salmon food consumption differs by age and body weight, with younger, smaller (1-ocean) age class of fish having twice the SCI of older fish. Finally, pink salmon eat a constant percentage of body weight per day for all sampled size ranges, although they show an ontogenetic prey shift from small zooplankton to squid as their body weight increases (Fig. 2). Bioenergetic models indicate that the body weight decreases in pink salmon in recent years may have shifted the adult pink salmon prey base substantially away from squid towards zooplankton.

Measures of density dependence, by comparing CPUE of salmon to salmon stomach contents, reveals a weak inverse relationship between CPUE and SCI of squid and euphasiids in all salmon species. This trend is dominated by the 1995 data, a time of extremely high CPUE and low stomach contents weight.

Finally, the ratio of individual diet diversity to group diet diversity varies interannually in a statistically similar manner between salmon species, regardless of differences in total diversity or prey items consumed, and independent of SCI or density dependence. This indicates that a factor other than prey type or availability may act on salmon feeding behavior, possibly arising from prey patchiness forced by interannual differences in pelagic mixing.

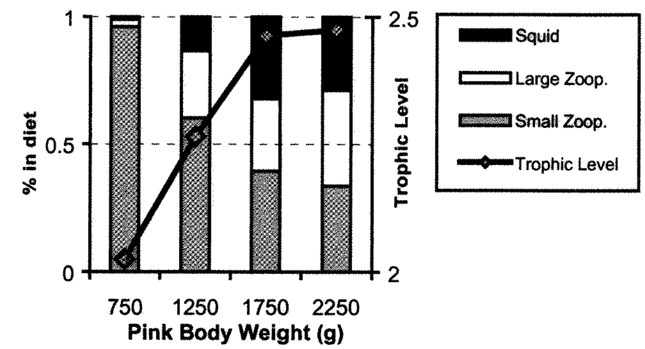

Fig. 2. Change in July high seas diet and trophic level of maturing Gulf of Alaska pink salmon with changing body size. Shift in mean body weight of some stocks between 1970s and 1990s is between 1750g and 1250g size categories above.