Ocean Distribution, Feeding Ecology, and Return of Pacific Salmon in the 1997 El Niño Event Year

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Key Words: return, Japanese chum salmon, body size, CPUE, feeding ecology, Pacific salmon, 1997 El Niño event year

We investigated the effect of oceanic environment related to the 1997 El Niño event on the offshore distribution, migration, and feeding ecology of Pacific salmon in the North Pacific Ocean and the Bering Sea, and return pattern of Japanese chum salmon in 1997.

Numbers of adult chum salmon returning to Japan in 1997 were 54 million fish in Hokkaido and 22 million fish in Honshu, and totaled about 76 million fish (Fig. 1). This run size was about 85% of the 1996 record level (88 million fish). Their run pattern showed extreme fluctuation by area and run timing. In Hokkaido, the early run, which returned by October, was 10.4 times greater in abundance and 6.1 times higher in return rate (survival rate from release to return) than the late runs, which returned after November in 1997. The 1997 abundance and return rate of early runs was greatly increased in the Okhotsk and Nemuro regions compared to the previous five-year means. However, abundance and return rate of Japan Sea populations and some of the late runs was decreased. In Honshu, returns were higher in the Pacific area and lower in the Japan Sea area than the previous five-year means. A similar fluctuation of salmon run pattern was observed in the Pacific Rim nations in 1997 (NPAFC 1997). For instance, although the run size of Fraser River sockeye salmon was of the magnitude predicted, the Bristol Bay sockeye catch and total run were the lowest since 1978. Japanese pink salmon run size was also at an extremely low level, however, Russian pink catch was at or near record level.

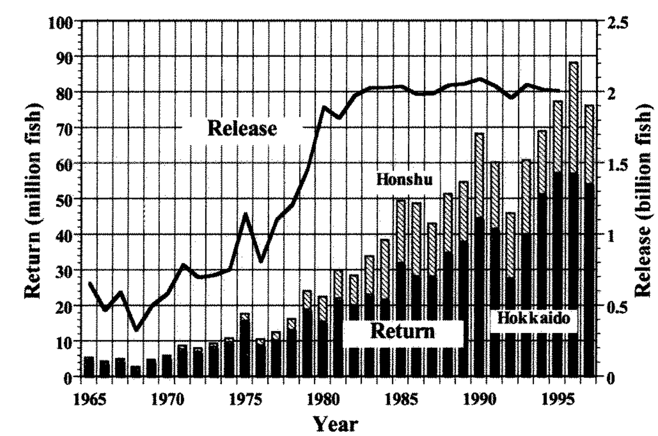

Fig. 1. Changes in numbers of adult returns and juvenile releases of chum salmon in Japan during 1965-1997.

A significant positive relationship between the return rates of age-3 adults (R_3) and age-4 adults (R_4) was observed in the Hokkaido Japan Sea chum salmon populations during the 1989-1992 brood years: $R_4=5.891R_3$ ($r^2=0.969$, $P<0.025$) (Fig. 2). The return rate of age-4 adults in 1997 was actually 0.97%, although it was estimated as 2.65% from the above formula and the return rate (0.45%) of age-3 adult in 1996. This result suggests that age-4 adults of the 1993 brood-year cohort might have had a lower return rate in 1997 because of some influence during the offshore migration period from autumn of 1996 to summer of 1997, despite the fact that their return rate at age 3 was high.

Fork length data of age-4 female adults returning to 11 rivers (Ishikari, Abashiri, Kushiro, Nishibetsu, Shari, Shibetsu, Shiriuchi, Shizunai, Teshio Tokachi, and Yurappu rivers) in Hokkaido from 1953 to 1997 were used to quantify change in body size at maturity of chum salmon. The fork lengths showed a decreasing trend from the late 1970s to the early 1990s, minimized in 1994 (average 626 mm). However, it has recently increased again, and averaged 649 mm in 1997 (Fig. 3). A significant negative relationship between the population size of the

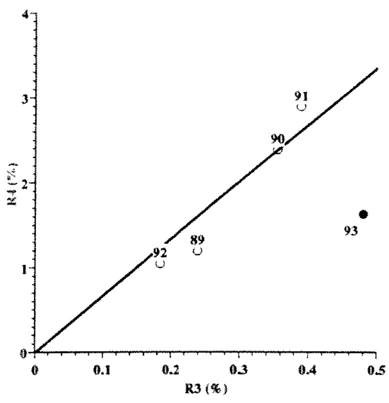

Fig. 2 Relationship between the return rates of age-3 adults (R_3) and age-4 adults (R_4) in the Hokkaido Japan Sea chum salmon populations during the 1989-1993 brood years.
R_4=5.891 R_3 (r^2=0.969, P<0.025)

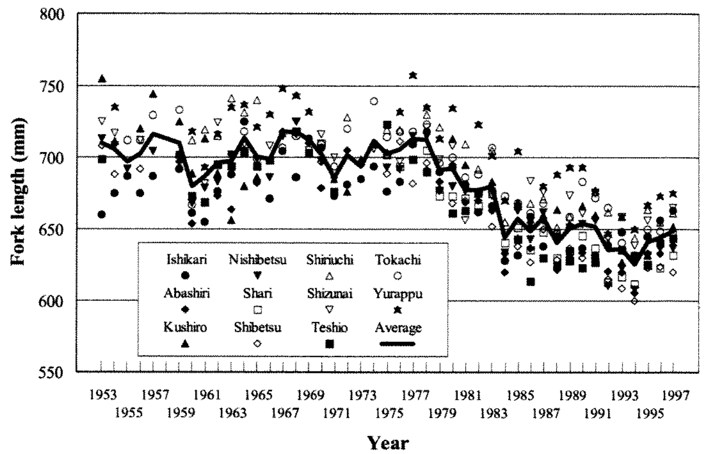

Fig. 3. Changes in annual means of fork length in age-4 female adults returning to 11 rivers in Hokkaido from 1953 to 1997.

Hokkaido chum salmon population and annual mean fork length of age-4 adult chum salmon returning to 11 rivers was observed in Hokkaido (r^2=0.7494, P<0.001).

A significant negative relationship between run season (month) and fork length was observed for the Tokachi and Shibetsu river populations in 1997. The younger adults (age 3) showed a more significant trend than the older adults (age > 4). This result supports the hypothesis of "precedent migration of larger individuals which have higher growth rate" (Kaeriyama 1996). That is, early-run populations with a high growth rate were generally greater in population size and higher in return rate than late-run populations with a low growth rate in 1997.

Oceanographic data acquired on board the research vessel *Oshoro maru* indicated that the average sea surface temperature (SST) in the central Gulf of Alaska was 2.5°C warmer in 1997 than in 1996. The warmer summer surface temperature in the Alaska gyre in 1997 may be related to the El Niño event through an atmospheric connection (Freeland 1998).

Catch per unit of effort (CPUE: number of fish per tan of research-mesh gillnets) of Pacific salmon was distinctly greater in the Bering Sea than in the Gulf of Alaska, central, or western North Pacific Ocean in the 1990s. In the Gulf of Alaska, total CPUE of Pacific salmon recently showed decreasing trends (Ishida et al. 1997). CPUEs of chum, pink, and coho salmon in 1997 were lower than those in normal years. In the Bering Sea, on the other hand, total CPUE of sockeye, chum, and pink salmon was about two times higher in 1997 than in other years, although the total CPUE was usually almost constant. Especially, CPUEs of pink and chum salmon in 1997 were significantly higher in the Bering Sea and lower in the Gulf of Alaska than previous three-odd-year means (t-test: P<0.001, Fig. 4).

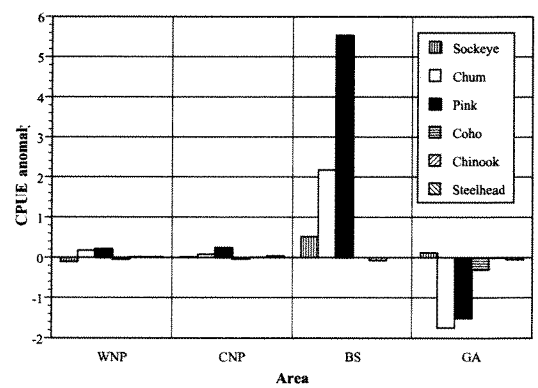

Fig. 4. CPUE anomalies of Pacific salmon in western (WNP) and central (CNP) North Pacific Ocean, the Bering Sea (BS), and the Gulf of Alaska (GA) in 1997.

In the Gulf of Alaska, squid, especially *Berryteuthis anonychus*, dominated in stomach contents of Pacific salmon, except for chum salmon, which mainly fed on gelatinous zooplankton from 1994 to 1996 (Myers et al. 1997). In 1997, however, the dominant prey shifted from squid to zooplankton (euphasiids and copepods) in pink and sockeye salmon, and to fish in steelhead trout. The level of food niche overlap, which was calculated by the simplified Morishita index, among Pacific salmon was much lower in 1997 than in 1994-1996.

These data indicate that Pacific salmon, which annually distribute in the Gulf of Alaska during spring-summer seasons, migrated from the Gulf of Alaska, where SST and food resources changed, to the Bering Sea and increased the CPUE in the Bering Sea in 1997.

These results suggest that salmon distribution was concentrated in the Bering Sea, leading to more intra- and inter-specific competition among Pacific salmon populations in 1997. Furthermore, the 1997 run pattern of Japanese chum salmon, as well as other Pacific salmon populations in the North Pacific Ocean, may have been influenced by increased competition, and showed extreme fluctuations by area and run timing.

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