Cyclic Fluctuations in Chum Salmon Abundance along the Pacific Coast of Hokkaido, Japan

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Some chum salmon stocks are known to exhibit a two-year cyclic variation in their biological parameters, such as age at maturity, size, marine survival, and abundance (Salo 1991). Previous studies suggest that this variation appears to be associated with pink salmon, which have a prominent two-year cyclic pattern of abundance (Salo 1991; Ruggerone and Nielsen 2004). On the Pacific coasts of Hokkaido (East Pacific, EP; West Pacific, WP) abundance of adult chum salmon, calculated on the basis of coastal and river catches, shows odd- and even-year fluctuations after the 1998 brood year. A similar fluctuation is also observed in chum salmon caught in the southern region of the Sea of Okhotsk, adjacent to the Nemuro Strait (Nemuro, NE). The objective of this study was to explain a possible mechanism causing the cyclic pattern of returning adult chum salmon.

Of 48 chum salmon river-stocks along the Sea of Okhotsk and Pacific coasts of Hokkaido, 11 stocks from the Pacific coast illustrate cyclic fluctuations in abundance for brood-years 1998-2004. Only one stock from the Sea of Okhotsk exhibit these cyclic fluctuations. Findings demonstrated that a few stocks from rivers on the Pacific coast cause the cyclic patterns in brood-year abundance in the NE, EP, and WP regions. In general, mass mortality of chum salmon occurs during early marine residence and frequently affects the brood-year abundance of returning adult salmon (Saito and Nagasawa 2009; Saito et al. 2011). The mass mortality is believed to be associated with biological interactions, like predation (Duffy and Beauchamp 2008), and oceanic conditions (Saito et al. 2011). In this study, effects of Asian pink salmon and sea surface temperature (SST) on brood-year abundance were tested to examine whether this could explain the cyclic fluctuations of these chum salmon stocks.

In Japan, spawning stocks of pink salmon are mainly distributed in rivers along the Sea of Okhotsk coast, and no abundant spawning stocks exist in rivers on the Pacific coast of Hokkaido. This suggests that chum salmon from the Pacific coast have no interaction with pink salmon during their freshwater and coastal residency. After leaving Japanese coastal waters, juvenile chum salmon migrate to the Sea of Okhotsk and remain there from August through November of their first ocean year (Urawa 2000; Urawa et al. 2004). During this period, Japanese juvenile chum salmon intermingle with Asian juvenile pink salmon originating in Japan and the Russian Far East (e.g., Ogura 1994; Nagasawa 2000). However, unlike chum from the Pacific coast, almost all Japanese chum salmon from rivers located on the Sea of Okhotsk coast do not show cyclic fluctuations in abundance. Juvenile chum salmon from both regions of Hokkaido co-mingle in the Sea of Okhotsk, so it was unexpected that fluctuations in brood-year abundance would occur only for stocks from the Pacific coast. Based on the distribution patterns of both chum and pink salmon, we hypothesized that juvenile chum salmon may overlap the distribution of maturing pink salmon on their homeward migration before both species enter the Sea of Okhotsk.

Of the 11 stocks showing cyclic fluctuations in abundance in brood-years 1998-2004 (the year of sea entry, 1999-2005), eight stocks were negatively correlated with catches of Asian pink salmon during 1999 to 2005. Adult chum salmon scales collected from age-0.3 adult fish in the Tokachi and Yurappu Rivers were measured to examine whether the growth during the first ocean year was affected by the presence of Asian pink salmon. These two stocks are representative of stocks from the Pacific coast. Circuli spacing on four areas of the scale (1-5th circulus, 5-10th circuli, 10-15th circuli, and 15th circulus-1st annulus) did not show cyclic growth fluctuations for either stock. This suggested there was no evidence that growth in the first ocean year was affected by the presence of pink salmon.

To detect if there was an effect of SST on chum salmon abundance, brood-years 1998-2004 from four of the most abundant stocks on the Pacific coast (Tokachi, Kushiro, Hiroo, and Yurappu) were compared to SST fluctuations. To clarify the spatial and temporal relationship between brood-year abundance and SSTs, the time series of chum salmon abundance was correlated with the corresponding average 10-day SST for a 1°X 1° grid from 40ºN to 60ºN and 140ºE to 180ºE during March of the year of sea entry and May of the second ocean year (i.e., from time of sea entry to the end of the first winter at sea). For comparison, the same analyses were repeated for brood-years 1991-1997, which did not show cyclic fluctuations in abundance.

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The most remarkable difference between the two sets of data was found in the results for the coastal areas around Hokkaido. From March through July, the four stocks showed statistically positive correlations between brood-year abundance and SSTs in coastal waters for brood-years 1998-2004, but not for brood-years 1991-1997. These correlations indicate that coastal SSTs around Hokkaido fluctuated with the same cyclic pattern as chum salmon abundance during the spring-early summer of 1999 through 2005, and this pattern of SSTs may have affected the survival of juvenile chum salmon from the EP and WP regions.

When the time series was extended to brood-year 2006, the abundance of brood-years 1998-2006 was re-defined as the total number of returning adult salmon of age-0.1 to -0.3 fish in each brood year. The coastal SSTs no longer showed statistically significant correlations with abundance of either the EP or WP regions, although the catch of Asian pink salmon was still a valid variable to explain the cyclic fluctuation of brood-year abundance in the EP region. A comprehensive mechanism is not still clear, and does not yet explain how recent increases in Asian pink salmon production may negatively affect the survival of juvenile chum salmon originating on the Pacific coast of Hokkaido. We should consider two possibilities for future research: (1) a direct impact of pink salmon on chum salmon, and (2) a spurious interaction between pink and chum salmon. The former may include predation by adult pink salmon on juvenile chum salmon, and the latter indicates an unknown environmental factor that acts positively on the pink salmon abundance, but negatively on chum salmon abundance.

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