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Population dynamics of Japanese pink salmon

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Population dynamics of Japanese pink salmon

Abstract: We examined the joint effects of density dependence, climatic variation, and hatchery release on the population dynamics of the pink salmon *Oncorhynchus gorbuscha* around Hokkaido Island, Japan, from 1969 to 2003. The number of fry released by hatcheries, winter temperature, and abundance of pink salmon increased significantly during this period. The statistical analyses indicated that density dependence and climatic variation, but not hatchery release, are important for understanding the population dynamics of pink salmon. The patterns of covariation between climatic variables and population growth were consistent with previous hypotheses: the population growth rate was enhanced by mild winters, high rainfall during fall seasons, and an intensified Aleutian low. Our results showed that the recent increase in pink salmon catch is explained by climate change alone, without necessarily involving increased hatchery release.

The understanding of mechanisms regulating fish abundance is a central issue in fisheries science. Density dependence and climatic variation are two of the most important factors affecting population dynamics of fishes. In addition to density dependence and climatic variation, the level of artificial propagation is becoming an important factor affecting population dynamics of fishes. Hatchery programs consisting of the mass release of artificially propagated fishes have spread all over the world to supplement wild populations and to increase fishery harvest. However, the effectiveness of hatchery programs is questioned by recent studies.

As mentioned above, there are three possible factors–density dependence, climatic variation, and hatchery release–affecting population dynamics of fishes. In this study, we examined the joint effects of density dependence, climatic variation, and hatchery release on the population dynamics of the pink salmon *Oncorhynchus gorbuscha* around Hokkaido Island, Japan.

The catch and release of Japanese pink salmon increased dramatically over the last quarter of the 20th century (Fig. 1). The average catch increased from 1-2 million in the 1970-80s to near 10 million in the 1990s. The number of fry released held constant around 140 million per year after 1990. Despite the constant number of fry released, the catch of pink salmon nonetheless fluctuated greatly; the year-to-year difference is two-fold in the recent decade. Even-numbered years dominated after 1994, although odd-numbered years dominated before 1975.

We used modified Ricker population model incorporating several predictor variables (Dennis and Otten 2000). As predictors of the population growth of pink salmon, the following variables were used: (1) mild winter index (MWI) (MWI is the first principal component of monthly mean temperatures in Abashiri during the two years after a given year and is positively correlated with winter air temperatures), (2) total rainfall between September and October in Abashiri (*i.e.*, the periods of upstream migration and spawning), (3) the winter Aleutian low pressure index (ALPI), and (4) the number of pink salmon fry released by hatcheries along the coast of the Okhotsk Sea.

The population growth rate of pink salmon was enhanced with increasing MWI, with increasing rainfall during upstream migration of two years before, with increasing ALPI of the last year, and with decreasing catch of two years before. The three climatic variables–MWI, ALPI, and rainfall–were all statistically significant (likelihood ratio test, all $P < 0.035$), yet the number of fry released the year before was not statistically significant (P = 0.783). The PBLR test of Dennis and Taper (1994) identified significant density dependence only when the climatic variables were incorporated (P = 0.012). Furthermore, the Monte Carlo simulations using the best Ricker population model suggested that climate warming could explain the recent increase in the pink salmon catch without necessarily involving increased hatchery release.

The patterns of covariation between climatic variables and the population growth of pink salmon are consistent with previous studies. The population growth of pink salmon was significantly enhanced by mild winters, high rainfall during fall season, and an intensified winter Aleutian low. Several empirical studies have indicated the following: mild winters prevent spawning grounds from freezing, which in turn decreases egg mortality (reviewed by Heard 1991); high rainfall increases river discharge, which in turn enhances the upstream migration of adults, increases available spawning ground, and increases oxygen concentration (reviewed by Wickett 1958; Heard 1991); and the annual catch of Pacific salmon and the Aleutian low pressure index exhibit long-term parallel trends (Beamish and Bouillon 1993). While Japanese pink salmon populations are near the southern limits of their natural range, a severe winter could still cause the freezing of spawning grounds because average winter temperatures (January and February) in Abashiri ranged from -10.4C° to -3.5C° during the study periods.

The following is an overview of our deductions pertaining to the recent trend in the population dynamics of Japanese pink salmon. Remarkable increases in abundance occurred in the 1989 odd-year and 1990 even-year classes because of very warm winters for both year classes (Fig. 1). Further increase in abundance occurred in the 1992 even-year class because of very high rainfall during the fall of 1992, and even-numbered years dominate after 1994 (Fig. 1). Similarly, further increase in abundance occurred in the 2001 odd-year class because of very high rainfall during the fall of 2001. In the recent decade, winters were relatively warm and the population size was at a historically high level.

The population dynamics of pink salmon in Japan are largely influenced by density dependence and climatic variations. The recent increase in the pink salmon catch is explained by climate change alone, without necessarily involving increased hatchery release. In addition to hatchery programs, we strongly propose alternative management tools such as habitat improvement, removal of dams, and/or installation of efficient fish ladders as a means to ensure better conservation of salmon resources. Such ecological management tools will guarantee long-term sustainability of salmon resources.

References:

Beamish, R.J. & Bouillon, D.R. (1993) Pacific salmon production trends in relation to climate. *Canadian Journal of Fisheries and Aquatic Sciences*, **50**, 1002-1016.

Dennis, B., & Taper, M.L. (1994) Density dependence in time series observations of natural populations: estimation and testing. *Ecological Monographs*, **64**, 205-224.

Dennis, B. & Otten, M.R.M. (2000) Joint effects of density dependence and rainfall on abundance of San Joaquin kit fox. *Journal of Wildlife Management*, **64**, 388-400.

Heard, W.R. (1991) Life history of pink salmon (*Oncorhynchus gorbuscha*). *Pacific Salmon Life Histories* (eds C. Groot & L. Margolis), pp. 119-230. UBC Press, Vancouver.

Wickett, W.P. (1958) Review of certain environmental factors affecting the production of pink and chum salmon. *Journal of the Fisheries Research Board of Canada*, **15**, 1103-1126.

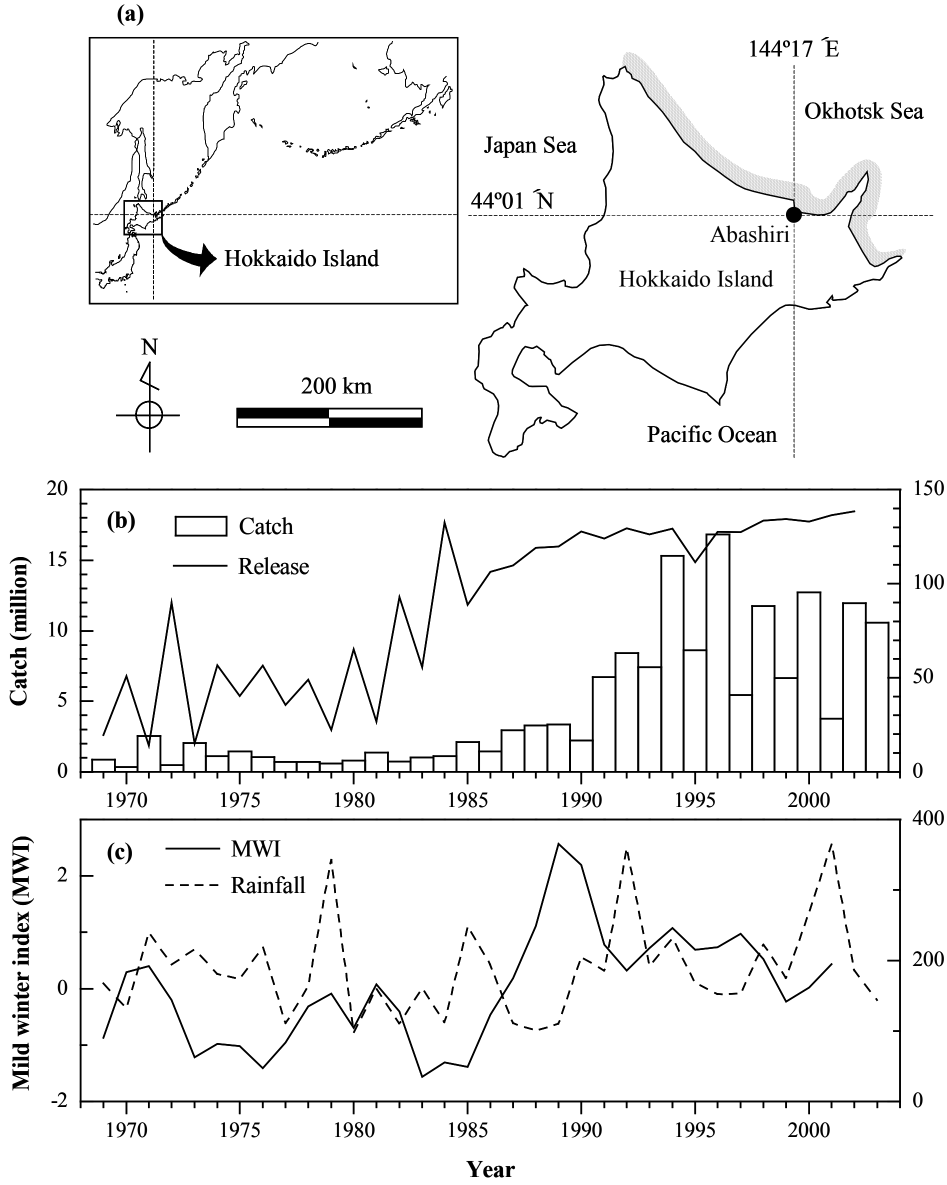

Fig. 1. (a) Location of the main fishing grounds for Japanese pink salmon (dotted area) and the Abashiri meteorological observatory (filled circle). (b) Long-term changes in pink salmon catches (open bars) and number of fry released by hatcheries (solid line) in eastern Hokkaido, Japan, along the coast of the Okhotsk Sea. (c) Long-term changes in mild winter index (MWI) (solid line) and total rainfall between September and October in Abashiri (dashed line). MWI is the first principal component of monthly mean temperatures in Abashiri during the two years after a given year.