Fluctuations in Abundance of Pink Salmon (*Oncorhyncus gorbuscha*) in the North Pacific Ocean

M.J. Jaenicke
Alaska Department of Fish and Game, Dillingham,
AK 99576 USA

O.A. Mathisen
University of Alaska Fairbanks,
AK 99775 USA

and

V.I. Radchenko
Pacific Research, Institute of Fisheries and Oceanography,
Vladivostok, Russia.

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Commercial exploitation of all species of salmon in Alaska commenced in 1878. It is assumed that major changes in the commercial catches reflect similar major changes in total abundance. These have been remarkably synchronous for all five species in Alaska. Following the initial harvest of virgin stocks, there was a gradual buildup of total yield, which remained high for more than half a century. In the fifties catches or abundances decreased for all species and remained low until the seventies, when salmon stocks again started to gain in strength. Today abundances are at the highest levels ever recorded.

Environmental data, such as time series of air temperatures, demonstrate similar changes. The period with low pink salmon catches in S.E. Alaska corresponds to a lowering of winter air temperatures. Air temperatures observed here at various locations follow the same temporal pattern, only the amplitude varies. Environmental changes can thus be described by observations from one location. The reduced production may be due to a lowering of the food production and a shortening of the growing season for the juvenile salmon.

Pink salmon is the dominant species in both S.E. Alaska and in the Russian Far East. The initial high level of catches of Pacific salmon in Russia lasted until the late forties. After a couple of decades of low abundance, the stocks started to gain in strength, which still continues today. However, the recovery was slower than observed in the eastern North Pacific Ocean. This similarity in pink abundance of the eastern and western stocks is most likely driven by large scale climatic factors.

INTRODUCTION

It has been known for a long time that variations in the catch curve may have the same general features in several districts when compared over periods of several years. Thus the Nushagak catch curve was almost identical with that of the Chignik system (Mathisen 1971). The last few decades have witnessed an expanding interest in the relationship between fish abundance and environmental variables such as coastal upwelling, temperature, precipitation, and others. A number of symposia have been held including Wooster (1983), Wooster and Fluharty (1985), Beamish and McFarlane (1989), Beamish (1995). Since the present paper deals with pink salmon (*Oncorhynchus gorbuscha*) in S.E. Alaska there are two papers of particular interest, namely Marshall (1993) and Francis and Hare (1994). The author of this first paper used time series analysis to forecast salmon catches in Alaska. The second paper relates decade-scale shifts in climate to similar shifts in abundance of salmon and zooplankton.

The present paper is continuing this line of inquiry by relating the mean monthly air temperatures to pink salmon production in S.E. Alaska. There are distinct relationships between the smoothed curves for air temperature and pink salmon abundance; but variability between years is great, proving that the final returns of pink salmon are governed by both the size of the escapement and the environment. This makes forecasting pink salmon extremely difficult and imprecise in nature when using only past catch levels. It will improve as better escapement data become available with more precise estimates of total runs, and clearer understanding of the relationship between survival and environmental variables is achieved.

MATERIALS AND METHODS

The catches for Alaska and S.E. Alaska have been obtained from the integrated fisheries data base of the Alaska Department of Fish and Game. Historically salmon was sold as a whole fish with different unit prices depending upon the species in question. After 1965 all trade has been on a weight basis. Since escapement is always reported in numbers of fish, the weight of catches has been converted to numbers by division with an average weight per fish. This declines through the fishing season. In the case of pink salmon the main reason is that the percentages of the smaller females increases as the season progresses. Normally average weight is determined at each processing plant by weighing about one hundred fish. There are errors involved due to selection of samples and counting of numbers of fish; but these have been considered to be randomly distributed, and no corrections have been applied.

The Russian catch statistics were taken from a publication compiled and issued in 1989 by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO). The data for 1900 - 1986 have been corrected by the late Dr. A.I. Chigirinsky. Corrected data from subsequent years have been provided by one of us.

For each species there are large year to year variations in reported catches. In order to bring out common trends between species the catches were expressed as a percentage of the maximum catch and a moving average of 5 years was calculated. A similar approach was used for air temperatures based on monthly mean values. These have been gathered at many places and for various lengths of time. The early records came from the U.S. Department of Agriculture (1921 & 1940), and then the U.S. Department of Commerce (1992) for the period 1950-1992.

No escapement records exist prior to 1960, however, Jaenicke (1995) has demonstrated a linear relationship between catch and total run of pink salmon in S.E. Alaska after this time (Fig.1). It therefore, becomes possible to use pink salmon catches as a proxy for total run. Practically this means that this salmon fishery is managed on a fixed fractional harvest of the total incoming run. Prior to 1960 most of the catches came from stationary traps. Although the total number of traps varied, those set in good locations were operated each year. This gave a stability to expended effort even though the catches of the five species varied drastically with pink and sockeye salmon being the dominant species in volume.

RESULTS

Total Catches in Alaska

On Fig. 2 are plotted the moving averages of the normalized commercial catches of all five species of Pacific salmon. For the numerically important species like pinks and chums (*O.keta*) the curves track each other very closely. For the more valuable species like

Fig. 1 Linear relationship between harvest and total return of pink salmon to S.E. Alaska during the period 1960-1995, (from Jaenicke 1995).

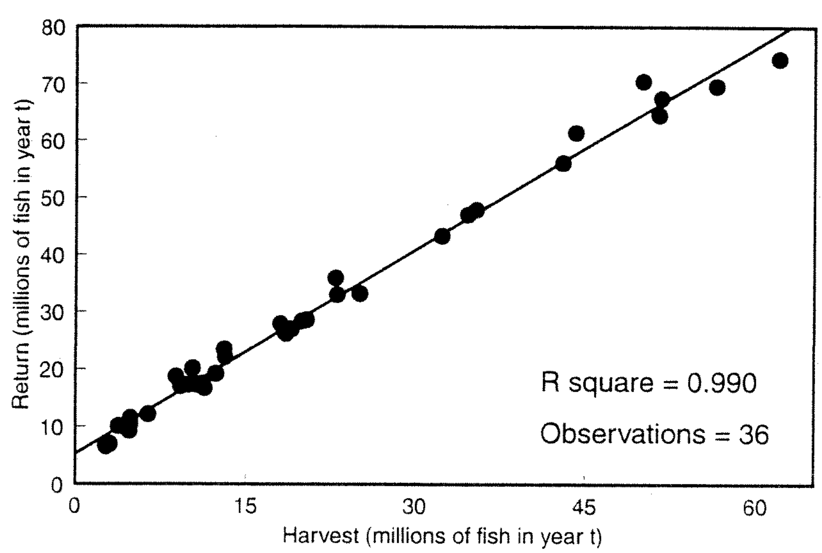
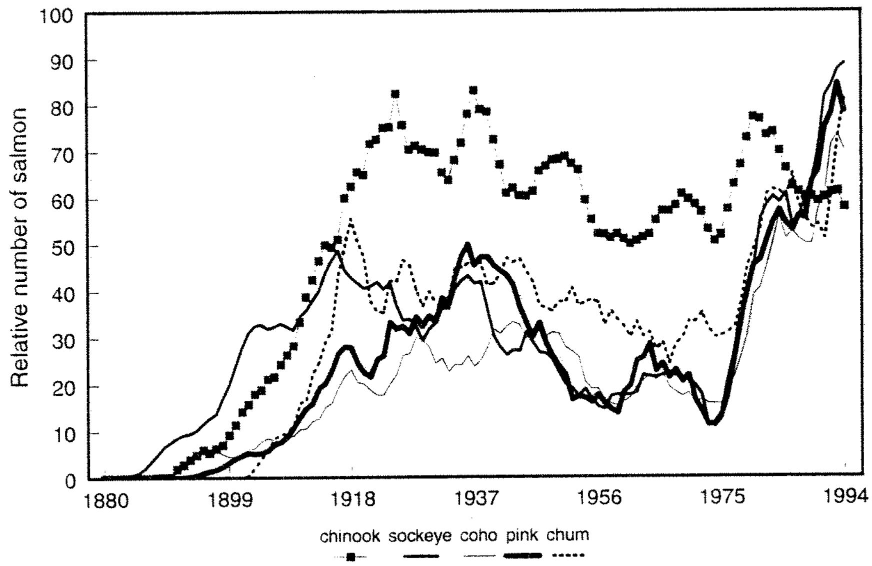


Fig. 2 Commercial catches of the five Pacific salmon species in Alaska, expressed as a 5-year moving average of percentages of maximum catch.



sockeye and chinook salmon the percentage catch of the total run is higher than for the less valuable species. Such a selective harvest rather than one proportional to abundance was especially pronounced for sockeye salmon during the early phases of commercial exploitation. Nevertheless, the catch curve for every species shows an initial period of high production with a decline appearing in the forties which lasted to the seventies. This was followed by a period of sharp increases in catch which is still ongoing.

Catches in S.E. Alaska

For the S.E. Alaska there was an initial emphasis on the harvest of sockeye salmon (Fig.3). But the two high production periods with a low one between them are well pronounced and covers the same time intervals as observed for Alaska as a whole. The recovery of chinook during the last period is less pronounced than for the other species. One reason might be a general increase in effort applied to this species inside and outside S.E. Alaska.

Russian Catches of Pacific Salmon

The catches in the Russian Far East are summarized in (Fig. 4). Pink salmon is the dominant species and a 5 year moving average of catches displays a similar pattern as seen in the eastern portion of the North Pacific Ocean with a period of stable production from 1910 to the early forties. Low production was seen in the sixties, but an increase in production commenced in the early seventies. The catch figures of chum salmon follow a similar picture with chum lagging pinks by approximately 10 years. In both cases the recovery during the last period is slower for pink and chum salmon than seen along the North American continent. If individual years are plotted, there occurs large variations. The catches of chinook and coho remain relatively high.

In spite of local variability within and between districts in the Russian Far East and the eastern side of the North Pacific Ocean, the catches of species like pink salmon display a similar pattern of two high production periods with an intervening period of low production. They could be generated by the same climatic factors as observed in the eastern North Pacific Ocean.

Air Temperatures in S.E. Alaska

Air temperatures have been measured at a number of places for varying lengths of time in S.E. Alaska. Although the amplitude differs from one place to the next, a variety of locations display the same common features. In this paper it is, therefore, assumed that temperatures measured in Juneau, the set of records covering the longest uninterrupted number of years, serve as a proxy for climatic changes in S.E. Alaska from 1909-1993. Three time periods have been considered in Fig. 5, namely two high production periods 1928-1938, and 1978-1988, a low one 1963-1973. For each period, representing 11 years, a monthly mean was calculated by combining daily high and low air temperatures. The three sets of monthly means were averaged, and considered as the -0- reference line. For each of the three sets deviations from this line have been plotted. The results (Fig. 5), are similar for the summer months for all three

Fig. 3 **Commercial catches of the five Pacific salmon species in S.E. Alaska, expressed as a 5-year moving average of percentages of maximum catch.**

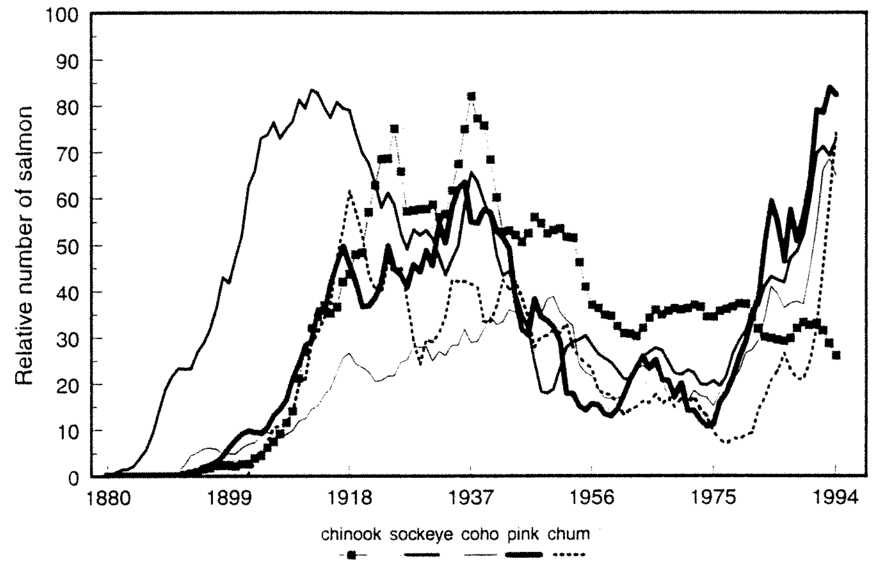


Fig. 4 **Commercial catches of the five Pacific salmon species in the Far East of Russia, expressed as a 5-year moving average of percentage of maximum catch.**

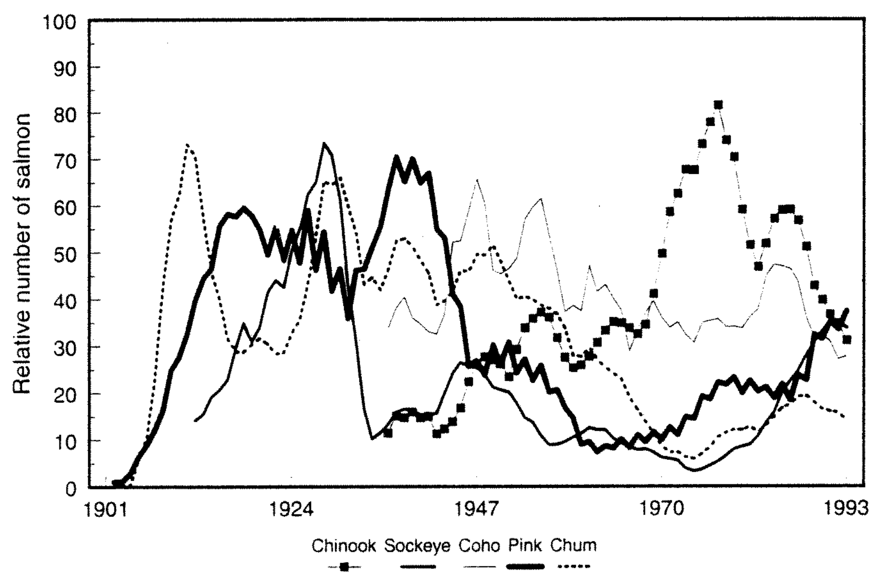
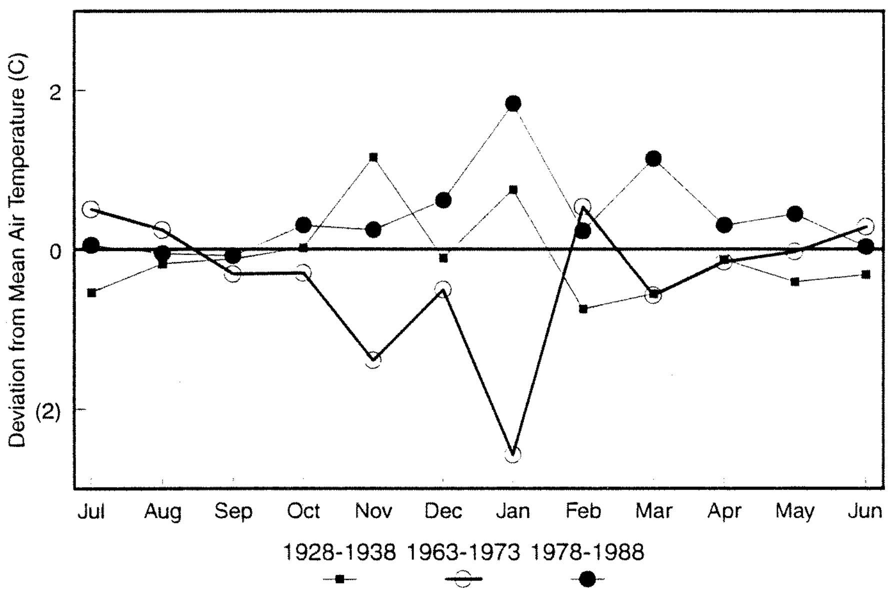


Fig. 5 Monthly means for three periods, 1928-1938, 1963-1973, and 1978-1988 have been averaged. The deviations of the three sets of monthly means from the overall mean have been plotted.



periods. The differences lie in the winter temperatures for October, November, December and January which are decidedly colder during the low production period.

The mean catches for three periods identified in Fig. 6 are essentially the same as used in Fig. 5. If the two figures are compared it is clear that low winter temperatures depress production of pink salmon in S.E. Alaska.

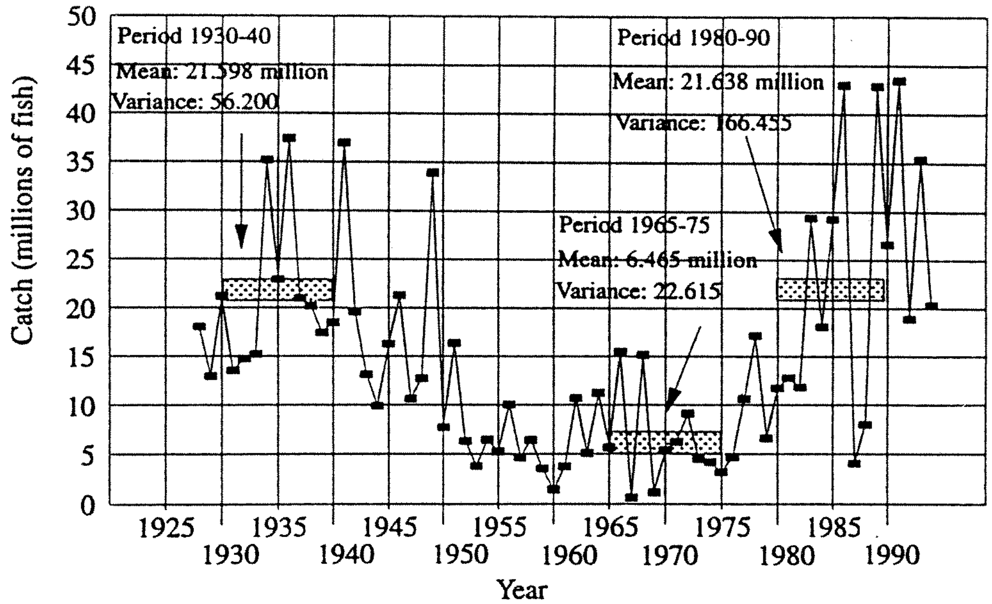
DISCUSSION

Attempts to use time series analysis of catches for prediction of future yearly salmon runs have only met with moderate success (Farley 1996). His errors varied approximately from ± 20-25 %. A univariate model performed just as well as one where environmental processes were included. The underlying variability is great if catches for individual years are plotted without any smoothing process.

Generally good growth of immature pink salmon during first summer in the inshore waters enhances their survival (Courtney 1997). But an observed variability in catches from year to year and within districts clearly indicate that other factors also are operating in conjunction with the temperature. Some can be abiotic in nature like precipitation while others are biological factors. Very little work has been done to clarify the role of predators and food competitors in the ecosystems occupied by salmon throughout its life span. For pink salmon a large escapement in one year may effect success of next spawning. It appears that the bottom fauna is enhanced from a large escapement and associated organic material introduced in the gravel, and developing scavengers may effect next year's egg deposition (Kline et al. 1990).

The changes observed in S.E. Alaska are only part of a larger picture of interannual variability in the North Pacific and the Bering Sea where a number of forcing mechanisms create atmosphere-ocean variability with varying time scales (National Research Council 1996). However, persistent changes in average air temperature will indicate major changes in pink salmon production with time lags not fully understood. This in itself is of great economic importance to the fishing industry. The present high salmon production has depressed the profit margin per production unit so any substantial reduction in catches carries immediate and large economic consequences.

Fig. 6 Average catches and associated variances of pink salmon in S.E. Alaska during three time periods, 1930-1940, 1965-1975, and 1980-1990.



CONCLUSIONS

Average winter air temperatures can serve as a proxy for total average pink salmon production over long time periods in S.E. Alaska. But the correspondence between salmon production and average air temperature is not accurate enough to use for yearly predictions of run sizes. While the emphasis in this paper has been on pink salmon in S.E. Alaska, it appears that the four other species of Pacific salmon there follow similar trends.

The salmon processing industry is in need of pre-season forecasts of long term and short term changes in abundance. The latter ones must come from other sources in addition to long term climatic changes.

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