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Comments on Marine Survival of Pacific Salmonids

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Mathews' review provides convincing evidence that post-smolt survival can have a substantial effect on adult year class strength in Pacific salmonids (with his proviso that the survivals he examined included part of the freshwater phase). A few comments on the search for underlying, causal mechanisms and the sampling theory underlying statements regarding significance will, I hope, complement his remarks.

The first comment regards the care that must be taken in establishing the statistical significance of correlations and regression coefficients in analyses involving oceanographic variables and marine survival. The most common oversight in these analyses is failure to account for intraseries correlation; samples in the time series are not necessarily independent, but may themselves be correlated. Because of this, when one computes the correlation between two time series or uses linear regression to estimate a model to describe one series in terms of the other, the standard confidence limits derived for independently chosen variables cannot be used. Differences between this and the correct procedure can be substantial. For example, a correlation of 0.7 between adjacent samples in one series will reduce the effective sample size by half.

There are basically two approaches to dealing with this problem. The first, called prewhitening, consists of removing the intraseries correlation by appropriate filtering. It is commonly used in time series, but has two drawbacks that make it less appealing in the application of concern here: (1) removal of all intraseries correlation reduces the chance of detecting a real effect of interest that involves dependence of one variable on another variable that contains intraseries correlation, and (2) removal of the intraseries correlation with the use of a fitted model may actually lead to underestimation of the significance of the resulting correlation coefficients (see Box and Pierce 1970; Durbin 1970).

The second approach is to account for the intraseries correlation by reducing the number of degrees of freedom from N, the number of samples, to an effective number of degrees of freedom which accounts for the lack of independence in the samples. This approach is based on the work of Bartlett who derived an expression for the variance of computed correlation coefficients (1946). A similar result for autocorrelations only was developed by Bayley and Hammersley (1946) and applied to fisheries by Sutcliffe et al. (1976). Box and Jenkins (1976, pp. 34 and 376) describe the application of Bartlett's results. Use of these results in fisheries involves two problems: (1) they are derived under the assumption of large N (rarely true in fisheries), and (2) the expression for the significance of each correlation is in terms of the true value of that correlation and all others at different lags. However, both of these problems can be overcome by using a finite number of properly chosen values of computed correlations. I have discussed this issue primarily in terms of correlation coefficients. A discussion of similar solutions to the same problem as it affects regression models can be found in Chelton (1983).

The second comment is to emphasize the fact that effects of environmental factors on salmonids may vary widely among species and locations. This lack of uniformity in response is apparent from Mathews' review, other papers in this volume, and the literature. Ocean temperature is a good example. Vernon (1958) found year class strength of pink salmon in the Fraser River to be negatively correlated with temperature encountered by the juveniles when entering the Georgia Straits. Van Hyning (1973) also found a negative relationship between sea water temperature during the first May and June of life and returns of chinook to the Columbia River for the years 1938-46. On the other hand, Botsford et al. (in preparation) found a significant positive correlation between sea surface temperature in the year Sacramento River chinook go to sea and eventual grilse, spawner, and catch returns. Ocean temperatures are also thought to influence migration routes and life history timing. Royal and Tully (1963) noted that during the warm water year 1958 Fraser River sockeye returned around the north end of Vancouver Island rather than through the Straits of San Juan de Fuca (also see Wickett 1975). Also, two extremely cold years while Bristol Bay sockeye were at sea resulted in two-to-four times as many fish remaining at sea for an extra year and returning as three year olds (Straty and Jaenicke 1980). This may be caused by southward displacement of these fish in the Gulf of Alaska. Changes in size distributions of chinook salmon returning to Columbia River hatcheries during the warmer water years 1957 and 1958 were attributed to an influence of oceanographic conditions on maturation rate (Junge and Phinney 1963). Higher ocean temperatures have a positive effect on growth rate of Bristol Bay sockeye (Straty and Jaenicke 1980), but sea surface temperature has a negative correlation with average weight in central California chinook (Botsford et al., in prep.). From these examples it is clear that we should not generalize a priori over species or locations with regard to the effect of a specific environmental factor, but rather must demonstrate a mechanism for each case individually. This is true not only because different salmon species at different locations may respond differently to their environment, but also because changes in the environmental factor may imply different oceanographic changes (e.g, currents, prey distribution) at different locations.

The third comment is that care must be taken in interpreting computed correlations and regressions because the environmental variables that we hypothesize are related to marine survival are often themselves not independent. It is well known that temperature and upwelling index are usually negatively correlated, and that interannual variations in temperature and sea level height are likely to be positively correlated (see Chelton this workshop). However, it is less obvious that the oceanographic variables that are correlated with survival may not affect marine survival at all, but rather smolt production in fresh water. For example, the positive relationship mentioned above between California central valley chinook and temperature during the spring of seaward migration (Botsford et al., in prep.) may be caused by a northward shift in marine prey that benefits the smolts, but may also be caused by an association between oceanographic conditions and precipitation. Stevens and Miller (1983) have demonstrated a positive relationship between winter flow rate in the Sacramento River and two indices of juvenile abundance in the following spring and fall. Also Kjelson et al. (1982) and Kjelson (personal communication) have shown a positive relationship between Sacramento River flows and both smolt survival through the San Francisco Bay Delta and abundance of juveniles in the estuary. A marine/terrestrial relationship such as this might also explain the coherence between deviations from average weight of Fraser River sockeye and temperature on the west coast of Vancouver Island three years earlier (Mysak et al. 1982). This lag implies oceanographic conditions are affecting the freshwater phase. Streamflow appears to be one variable that has a positive effect on many salmon stocks (Mathews and Olson 1980, Scarnecchia 1981, Ward and Larkin 1964, and others) and it is potentially related to oceanographic conditions.

My fourth comment is merely to reemphasize Mathews' closing statement. Identification of the oceanographic causes of fluctuations in Pacific salmonid populations really will take a concerted, cooperative research effort aimed at better measurement of both biological and physical parameters. However, economic studies indicate that the improvement in management brought about by the ability to forecast salmon abundance appears to be worth the cost (see, for example, Mathews 1971).

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