ABUNDANCE AND PRODUCTIVITY OF NATURALLY SPAWNING OREGON COASTAL COHO SALMON *(ONCORHYNCHUS KISUTCH)* IN RIVERS WITH AND WITHOUT HATCHERY PROGRAMS

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Abstract

Trends in the relative abundance and productivity of naturally spawning coho salmon in Oregon coastal river basins with and without hatchery operations were compared to estimate the long-term effects of large-scale hatchery programs. The comparisons of the two stream classes over 18 years (six generations) does not reveal any measurable declines attributable to interactions of hatchery fish with naturally spawning Oregon coastal coho salmon. Any cumulative effects of hatchery programs were so small in magnitude that they are obscured by other factors that determined abundance and productivity.

Introduction

Coho salmon have been propagated in hatcheries located in coastal rivers of Oregon throughout the twentieth century. It has been speculated that hatchery production contributed to the decline of coho salmon in this region (Weitkamp et al., 1995). Hatchery programs may have contributed to the decline through the cumulative effects of over harvesting in mixed-stock fisheries, and through the effects of competitive and breeding interactions of hatchery-bred salmon with naturally spawning populations. The mixed-stock fisheries are generally accepted as a major factor contributing to the decline in natural production, but the effects of interactions of hatchery-bred fish with naturally spawning populations are not as well understood.

I have attempted to determine the long-term effects of large-scale hatchery programs by comparing trends in the relative abundance and productivity of naturally spawning coho salmon in river basins with and without hatchery operations. The rationale for this comparison is that if the presence of hatchery-bred fish reduced the reproductive performance of naturally spawning populations, then trends in relative abundance and productivity for streams in river basins with hatcheries would be expected to reflect a greater decline over time than streams in basins without hatchery operations. This would result because the probability of straying of hatchery-bred fish from a specific hatchery into streams with naturally spawning populations would be greater for recipient streams within the river basin where the hatchery is located than for streams in other river basins the fish might enter.

Methods

The Oregon Department of Fish and Wildlife (ODFW) has conducted "standard spawning fish surveys" of salmon populations in selected coastal streams since 1950. I evaluated "area under the curve" (AUC) estimates of "run size" for the period 1981-1995 (Appendix II-E in Jacobs and Cooney, 1997) to compare trends in relative abundance and productivity in surveys in river basins with and without hatcheries. Estimates of AUC run size for calendar years 1996-1998 (S. E. Jacobs, Oregon Department of Fish and Wildlife, personal communication) were added to the data. The data include estimates of "run size" for 48 standard survey areas in Oregon coastal rivers. The combined data provide estimates of "run size" for 18 calendar years or six generations.

I standardized all data for miles surveyed, and partitioned the surveyed streams into two classes; streams in river basins with hatchery operations, and streams in basins without hatchery operations[1]. These classes will be referred to as the *hatchery* and *no-hatchery* stream classes respectively. For each class, I calculated the average "run size" and average productivity for each year. Values for missing data were not estimated; average values used in the analyses are the means of the values appearing in the published data sets.

[1] Basins included in the Hatchery class are Nehalem, Siletz, Yaquina, Alsea, Umpqua, Coos, and Coquille. Basins included in the No-hatchery class are Neacanicum, Elk Creek, Kilchis, Wilson, Tillamook, Nestucca, Beaver Creek, Yachats, and Siuslaw.

I used analysis of variance to test the null hypothesis that the average "run sizes" of the two classes are equal. I compared the rates of change of the fish/mile indices between classes by calculating linear regressions of the average fish/mile on calendar years for each class, and using the regressions as linear models to describe the rate of change of the index over time. I used an F-test to compare the slopes of the regressions to determine if the index values of the two classes changed at different rates. In this test, the F-statistic is computed by dividing the residual mean square of the regression of pooled data by the sums of the residual mean squares of the separate class regressions (Snedecor and Cochran, 1967).

I calculated productivities by dividing the estimated run size in a specific year by the estimated run size three years earlier for all cases where estimated run sizes are reported for consecutive generations. Productivities were not calculated in cases where there is missing data for either generation, or where the population estimate was zero for the parental generation. I used analysis of variance to test the null hypothesis that the average productivities of the two classes are not statistically different.

A Power Macintosh™ computer (Apple Computer, Inc.) and StatView™ software (Abacus Concepts, Inc.) were used for all calculations.

Results

The average fish/mile of the hatchery class is greater than that of the no-hatchery class in every year of the 18 year (six generation) interval 1981-98 (Figure 1). Analysis of variance of the fish/mile indices of the two classes indicates that the means of the classes are significantly different (P=.0001).

The slopes of linear models fitted to the hatchery and no-hatchery class data (-521 and -1.037 respectively) are not significantly different (P>.1), indicating that populations in river basins with hatcheries did not decline at a greater rate than those in the no-hatchery class basins during the observed period.

The mean productivity of the hatchery class (1.98) is slightly greater than the mean of the no-hatchery class (1.67). Analysis of variance indicates that the difference in means of the two classes during the five generation interval 1981-1995 is not significant (P=.533). The annual productivity of the two classes are strongly correlated (r=.757; P<.01), suggesting that the factors determining productivity are similar for both classes.

The patterns in year-to year variation in abundance and productivity is similar for both classes. For a given year, the trends in relative abundance and productivity tend to be similar in most surveys. For example, there is a strong correspondence between mean annual coast-wide productivity and the proportion of surveys that are below replacement (productivity less than unity) (Figure 2). This pattern indicates that the most important factors determining productivity act more or less uniformly on the entire metapopulation rather than on individual tributary streams, perhaps related to variation in climatic factors and to mortality factors encountered after juveniles have left their natal streams.

Discussion

Comparisons of relative abundance and productivity of the two stream classes over 18 years (six generations) does not reveal any measurable declines attributable to interactions of hatchery fish with naturally spawning Oregon coastal coho salmon. Although the presence of hatchery-bred fish may have had detrimental effects on natural production in some streams in some generations[2], the net, long-term effects of hatchery programs at the coast-wide level were negligible. Any cumulative effects of hatchery programs were so small in magnitude that they are obscured by other factors that determined abundance and productivity.

Reisenbichler and Rubin (1999) suggested that poor reproductive success of naturally spawning hatchery fish is an unavoidable consequence of "domestication" in hatcheries, and that "when such fish spawn naturally with wild fish, the productivity and viability of the naturally spawning population declines substantially". Based on the evaluations of the fish/mile indices of Oregon coastal coho salmon, it is clear that their prediction that "the fitness for natural spawning and rearing can be rapidly and substantially reduced by artificial propagation" was not realized. A decline in fitness would be manifest as a decline in populations size and productivity over time. Although Oregon

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[2] A similar evaluation by T. Nickelson of the Oregon Department of Fish and Wildlife (personal communication) using different data indicates that the presence of hatchery fish probably did negatively impact the productivity of naturally spawning populations in some streams in some generations.

coastal coho salmon clearly declined in abundance from 1981 to 1998, the results described above are not consistent with the notion that hatchery programs made a significant contribution to the decline.

The observations with Oregon coastal coho salmon suggest that the effects of hatchery programs on natural production are not uniform at all times. The findings of other studies, for example the frequently cited reports by Reisenbichler and McIntyre (1977), Chilcote et al. (1986), and Nickelson et al. (1986) suggest that different species may be more or less susceptible to the effects of hatchery programs, that the effects for a given species may be highly variable, and that the magnitude of the effects may be determined totally or in part by management practices.

Reisenbichler and McIntyre (1977) observed variation in survival of juveniles in experimental populations in different streams. They mated wild steelhead (anadromous rainbow trout, *Oncorhynchus mykiss)* and hatchery steelhead in all combinations, resulting in three progeny groups; wild x wild, hatchery x hatchery, and wild x hatchery. They measured the growth and survival of juvenile offspring in hatchery and stream environments, and observed that progeny of wild x wild and wild x hatchery crosses had on the average greater growth and survival in the stream environment, but hatchery x hatchery crosses showed the best performance in the hatchery environment.

Reisenbichler and McIntyre (1977) concluded that the differences in performance are genetically determined, and that interbreeding with hatchery fish would result in reduced fitness of wild populations. However, these generalizations do not necessarily follow from the data presented because the authors assumed survival to a juvenile stage to be an indicator of reproductive success or fitness but did not verify this assumption by observation of the reproductive success of returning adults from their experimental groups. Also, they did not verify that the differences in performance were "genetic differences" by including controls to test the plausible alternative hypotheses that the differences could be epigenetic or non-genetic in nature. However, it is interesting to note that the average survival of hatchery x wild hybrids was equal to or greater than that of progeny of wild x wild matings in two of the four streams observed.

Chilcote et al. (1986) attempted a more direct comparison of the relative reproductive success of naturally spawning wild and hatchery steelhead. They made crosses of indigenous Kalama River steelhead and Skamania Hatchery steelhead in all combinations, and released the progeny of the crosses into the Kalama River. Skamania Hatchery steelhead carried an allele of the enzyme alpha-glycerolphosphate (the AGP-1 allele) that was rare in the Kalama River steelhead. Therefore, the progeny of naturally spawning adults of hatchery origin could be identified among adult steelhead returning to the Kalama River by screening for the AGP-1 allele. They reported that naturally spawning hatchery fish were only 28 percent as successful in producing smolt offspring as were wild fish. A decline in productivity of this magnitude suggests that the effects of interactions of hatchery fish and naturally spawning populations may be greater in steelhead than in coho salmon, perhaps because of the greater complexity of steelhead life histories. Recurring declines of this magnitude in Oregon coastal coho salmon would have been manifest in evaluations of the fish/mile indices.

The cause of the reduced viability of hybrids reported by Chiclcote et al. can not be inferred from the data presented, but may be related to life history differences between stocks. The Skamania Hatchery summer-run steelhead stock differed from the naturally spawning Kalama River stock in life history traits, including timing of adult returns, spawning timing, timing of seaward migration, and number of years spent at sea. In addition, the Skamania Hatchery stock had experienced several generations of intentional selective breeding. The experimental design used by Chilcote et al. did not allow them to partition the effects of life history differences from the effects of hatchery background. If the reduced viability of naturally spawning progeny of hatchery-bred fish resulted from an unfortunate choice of the hatchery stock used in the experiment, the problem could be ameliorated by using a different donor stock for hatchery production.

Nickelson et al. (1986) were able to identify the causes of a similar reduction in reproductive success in the first generation following stocking of streams with hatchery-produced fingerlings. This report is of special interest because it addressed Oregon coastal coho salmon. These workers compared adult returns of coho salmon in 15 tributary populations that had been stocked with hatchery-produced “pre-smolts” (fingerlings) to 15 populations in unstocked streams. There was no significant difference in average density of returning adults between the stocked and unstocked streams. However, the stocking had measurable detrimental effects. First, indigenous juveniles were driven from the study areas because they were much smaller than the hatchery fish at the time of release. Second, there was a shift in the time-frequency distribution of spawning in the stocked stream populations because the returning hatchery-produced fish were the progeny of early spawning fish. The observation that juvenile densities were higher in unstocked streams than in stocked streams the following summer was considered to be indirect evidence that later spawning fish might have higher reproductive successes than earlier spawning fish. Thus, the use of only early-run hatchery fish coupled with severe overstocking of the available juvenile rearing habitat and subsequent competition between indigenous and hatchery-bred fry resulted in declines in reproductive success in stocked streams.

The observations reported by Nickleson et al. indicate that in this case, the cause of reduced viability of naturally spawning hatchery-bred fish was related to stocking methods rather than to some inherent deficiency of the hatchery-bred fish. This is an important observation because it illustrates that some, if not all, of the detrimental effects of the hatchery releases could have been ameliorated by alternative management actions. The authors noted that the effects of the stocking would probably have been less severe if they had limited stocking to the total biomass of juveniles that did not exceed the rearing capacity of the habitat, if the hatchery fry were equal in size and life stage to the indigenous fry, and if the life history pattern of the hatchery stock was more representative of the indigenous fish. It might be added that deleterious effects of stocking could be further minimized or eliminated by using release practices that reduce or avoid competitive interactions of the hatchery produced juveniles with indigenous fish, for example by releasing smolts rather than fry, and releasing the smolts at times and locations that would minimize their residence in the river basins.

Considered together, the Oregon coastal coho salmon experience and the observations of other workers indicate that the effects of hatchery programs on natural production are unique to each program and not consistent over all applications of artificial propagation. Additionally, most if not all of the detrimental effects of hatchery operations reported in the technical literature are consequences of management actions rather than intrinsic properties of artificial propagation, and can be ameliorated by judicious management of hatchery programs. The important implication of these considerations is that natural production and artificial propagation are not necessarily antagonistic. Judiciously managed hatchery programs can provide conservation and harvest opportunities concurrently.

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Figure 1. Average annual fish/mile of Oregon coastal coho salmon in river basins with hatcheries (circles) and without hatcheries (squares).

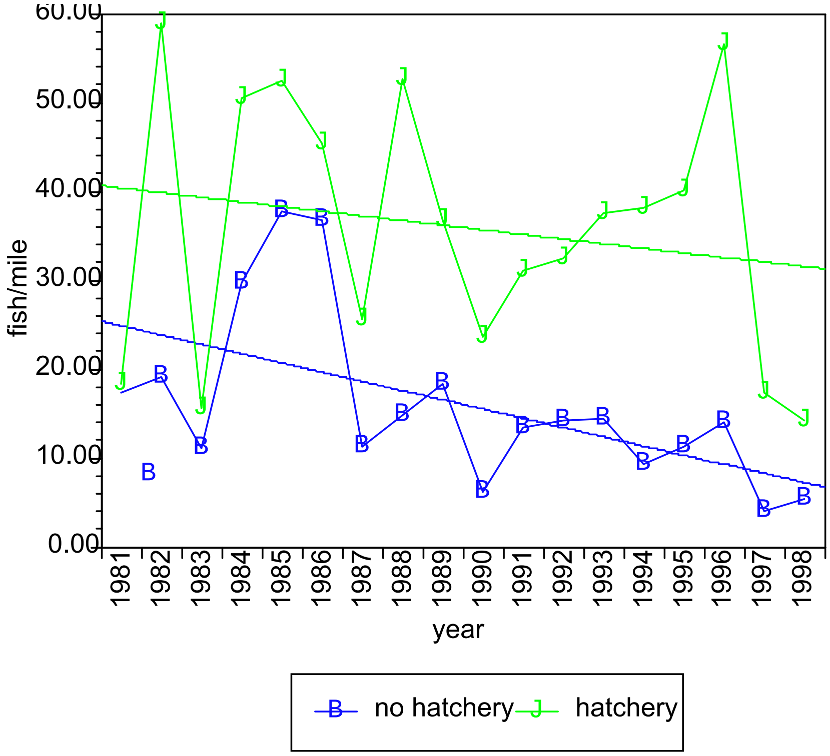

Figure 2. Relationship between mean annual productivity and the proportion of streams in standard spawning fish surveys that were below replacement from 1981-95.