Comments on the Mortality of Coho Salmon from Saltwater Release Facilities in Oregon

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Introduction

The authors and private sea ranching companies, Anadromous and Oregon Aqua Foods, are to be commended on their efforts to understand the complex factors affecting survival of their hatchery fish. The compilation of this extensive data set represents one of the most intensive tagging efforts ever mounted at either public or private Pacific salmon hatcheries.

It is not our intent to critize the techniques or statistics used to assess adult contribution from Oregon Aqua Foods and Anadromous hatchery releases. We recognize that there are inherent difficulties in estimating ocean catch and survival from coded wire tag recoveries. Instead we will comment on some of the underlying assumptions in these hatchery experiments, which were designed to evaluate potential increased production of adult fish. Specifically, we will address the following areas: (1) the adequacy of measures used to define the stage of smoltification, (2) the relatively poor contribution of underyearling fish when compared to releases of yearling smolts, (3) the rather considerable variability in survival observed in this and other studies in regard to size and time of release of juveniles, and (4) the need to expand these types of hatchery trials to partition the cause of density-dependent and size-dependent mortalities into ocean, estuary, and hatchery effects.

Smoltification Index

The authors state: "Significant changes in body coloration and shape accompany a metamorphosis from freshwater parr to a euryhaline smolt. Tagged groups were sampled to estimate the percentage of smolted and unsmolted juveniles in test populations--criteria for visual measurements are somewhat subjective. Nevertheless, changes in appearance are substantial between a juvenile that has smolted and one that has not." Classification of animals into parr and smolts was determined using five visual criteria. In our estimation, visual criteria are the least reliable indicators of smoltification since they show a poor correlation with numerous other smolt indices developed in recent years. In fact, the unreliable nature of visual criteria has led to the present interest of researchers in developing new smolt indices.

Recently, the adequacy of the classic terminology of "parr" and "smolt" has been brought into question when applied to the development of young Pacific salmon (Gorbman et al. 1982). A smolt is a larger and older

fish in which deposition of guanine in the scales and skin give the fish a "silvery" color that obscures the "parr" marks. This definition generally implies that this is the form that migrates to sea. The basis for dissatisfaction with this terminology is that the process of guanine deposition is easily reversible and not necessarily correlated with size or with physiological or biochemical changes.

A similar argument can be developed against the use of blood osmolality as the single measure of smoltification. Even after arrival in seawater, coho salmon smolts may not retain their optimum "osmolality" and their normal progressive development; some may revert to blood osmolality values more characteristic of the parr. It would seem prudent to employ a wider variety of techniques for more meaningful descriptions of the physiological, morphological, and behavioral changes that take place in developing salmonids.

Recent measurable features of osmoregulatory and metabolic development and migratory readiness that have been shown to have merit when taken in combination with other measures are: blood plasma levels of thyroid and interrenal corticosteroid hormones; appearance of enzymatic activity (ATPase) in the gills; swimming efficiency and stamina; and migratory behavior. We agree with the authors and understand why visual criteria of smoltification are not good predictors of marine survival. Modern techniques must be applied to accurately evaluate the importance of smoltification in ocean survival.

Comparison of Underyearling and Yearling Returns

In the present study differences in the contribution of underyearling and yearling fish were observed. Such differences may have been due to different proportions of parr and smolt forms that may have been present in the two age groups. Evidence from this and other studies can be presented suggesting that while yearlings undergo a more normal parr-to-smolt transformation, underyearling fish exhibit a retarded and incomplete juvenile development.

The authors have presented correlation coefficients for size and date of release versus survival of underyearlings that reveal the following decrease in correlative strengths: size at transport > size at release > date of release. For yearlings the opposite was observed: date of release > size at release > size at transport. In our opinion this reversal in the correlative relationships between underyearling and yearling performance is most likely a consequence of good smoltification in yearlings and poor smoltification in underyearlings. For underyearlings which are poorly smolted, size or freshwater growth is the most important factor determining subsequent marine survival. For yearlings, a critical physical size has been attained and is therefore less important than time of release. Time of release of yearlings is probably important for ocean survival because of at least two interacting factors. A primary time-dependent factor is the animal's developmental state (smoltification), which determines its ability to adapt to the marine environment. The other major factor is the variable ocean productivity which defines the conditions to which the fish must adapt.

In coho salmon the parr-to-smolt transformation usually occurs during the second year after hatching. Development of coho salmon may be compared with that of masu salmon in this regard (Kubo 1974). Kubo hypothesized that during the first year of development masu salmon undergo a "phase differentiation" that selects certain individuals for the parr-to-smolt

transformation during the second year. In studies of coho salmon, physiological measurements of either plasma thyroid hormone concentrations (Dickhoff et al. 1982) or gill Na^+-K^+ ATPase activities (Folmar and Dickhoff 1981) indicate a lesser degree of development during the first year than the second.

One procedure undertaken by the companies that may affect contribution is the period of seawater culture in ponds prior to release. For yearlings, but not for underyearlings, the period of saltwater culture between the time of transport and time of release has profound effects on survival. This may be due partly to protection from predation in the saltwater ponds while osmoregulatory capacity is developed during the critical period of seawater adaptation. Furthermore, a high degree of variability in seawater growth of yearling fish was observed. A significant relationship between size and escapement developed during this time. Several studies of coho salmon transferred to seawater net-pens have demonstrated that the timing of seawater entry is important for subsequent growth and survival (Clarke and Nagahama 1977; Bern 1978; Folmar et al. 1982). In the present study the relative importance of release date and size in yearlings may have been due to variation in the proportions of smolts in the populations at the time of seawater entry. The high degree of variability in seawater growth may have been due to parr reversion of incompletely smolted fish. Fish that entered seawater as smolts may have shown maximal growth during seawater residence, and these larger fish performed well after release (Figure 1). Thus, for yearlings, size at the time of seawater entry was not related to escapement but size became significantly related to escapement by the time the fish were released from the seawater ponds. For underyearlings, smoltification was retarded for the entire population so that parr reversion in seawater before release did not occur and could not influence the correlations with contribution.

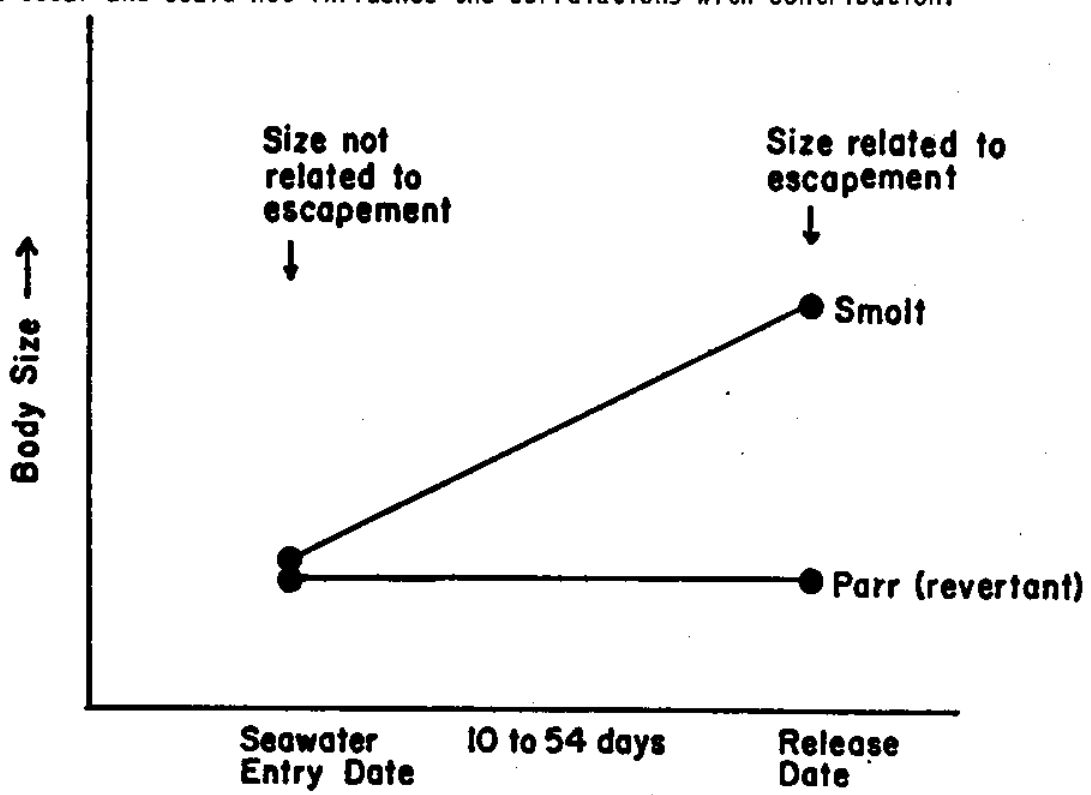

Figure 1. Possible growth pattern for yearling coho salmon resulting in a significant correlation between size and escapement with release date but not with seawater entry date.

Size and Time

The release experiments of Bilton et al. (1982) indicate strong size/time effects for returns of coho salmon in British Columbia. The adult returns varied 16-fold depending on either juvenile weight or time of release. These observations indicate the importance and potential in controlling size/time of releases at hatcheries, but the experiments do not indicate fully where or how these effects are induced in the system. Bilton viewed the juvenile release and adult returns as the boundary points in a "biological system whose central components as yet are imperfectly understood." They suspected that feeding and predation are the primary factors operating on juvenile survival, but they could have included physiological development and adaptation to seawater. Lack of information on status of smoltification in release groups complicates the interpretation of these size/time effects.

In similar experiments (Washington Department of Fisheries; Oregon Department of Fish and Wildlife) where size-groups were established by withholding food, the same criticism can be applied. In addition, there are unknown effects because of the retardation of growth through withholding food for the small size-groups.

The size/time effects on returns of coho salmon to Puget Sound or Columbia River hatcheries (Mahnken et al. 1982) show only a threefold spread in contribution. However, even this lesser range in noted effects suggests great value and potential in the control of size/time of juvenile salmonid release. Here, too, the concurrent smoltification state does not permit a separate analysis of that factor within the size/time variables.

For underyearling coho salmon, Gowan and McNeil observed that size at release had a major effect on returns. This might be expected because the independent time factor (not that which is merely expressed by older fish being larger) probably operates through the smoltification process. None of the underyearling juveniles would have begun the smolt cycle, so that only size effects are expected (and noted) in the survival of these groups. On the contrary, for yearlings, which are smolting, both size and time effects were observed, with time apparently being more influential.

Hatchery Trials

An experiment to separate the independent effects of release size, time, and smoltification state has yet to be performed. One such experiment is planned using an advanced photoperiod to accelerate smolting. In this way identical size-groups, all with maximum growth potential, can be released at the same times but with known large differences of smoltification. Returns should then reflect independent effects caused by all three variables: release size, time, and state of smoltification. From the analysis of returns, the influence of the separate variables can be partitioned. The independent, but probably critical, role of smoltification on ocean survival can then be evaluated. Direct studies in coastal areas, on the surviving juveniles, could then evaluate the separate effects of size and time at release, which probably operate through feeding and predation.

Many salmon biologists have held the opinion that the most important factors determining salmonid survival are of the freshwater environment. It has become clear that the marine environment is at least as important. However, it would be unwise to trade one narrow view for another by focusing solely on the ocean as the determining factor in salmonid

production. The ultimate ocean survival of salmonids is the result of the interaction of marine conditions with the physiological state of the fish, which was predetermined by its freshwater experience. Therefore, it is necessary that research on the ocean survival of salmonids include the developmental history and smolt quality of evaluated populations.

The large-scale salmonid hatchery systems in the Columbia River Basin offer unique opportunities for research. Similar systems and controls over recruitment are not available for any other marine species. As information becomes available on the relationships between freshwater rearing conditions and specific ocean conditions that challenge fish adaptability, techniques may be developed to optimize the degree and timing of smolt development.

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