**"A REVIEW OF RELATIVE FITNESS OF HATCHERY AND NATURAL SALMON"**
By: Berejikian and Ford

## Summary:

The authors review several studies of relative fitness of hatchery and natural salmon and summarize the results. They place the studies in four categories that are thought to result in important differences in relative fitness: (1) Non-local, domesticated hatchery stocks; (2) local, natural origin hatchery stocks; (3) local, multi-generation hatchery stocks; (4) captive farm stocks. The authors find relative fitness estimates that vary considerably between and within these different categories. Methods for estimating relative fitness also varied considerably, and experiments were not consistently measuring the same quantity. Over the range of steelhead studies examined, for example, fitness quantities measured included egg-to-parr, adult-to-adult, smolt-to-adult, and adult-to-fry, adult-to-smolt. They found numerous studies that estimated the relative fitness of hatchery and natural salmon, but the studies are not well distributed with respect to species or management scenario. The authors conclude that for stocks that fall into categories (1), (2) and (4) above, study information can be used to reduce the range of values used when estimating lambda. For stocks that fall into (3), they conclude, it will be prudent to continue to use a wide range of assumptions about relative fitness when estimating lambda.

## General Comments:

Since the purpose of this paper is to provide guidance on parameterization of productivity models and federal agencies need to decide which models to use at this time, it would be helpful if the paper could be expanded to include a summary of the ongoing and new studies that have been undertaken or will soon be funded that will improve our understanding of the relative fitness of hatchery-origin fish. For example, in response to the 2000 Hydro BiOp and its RPA 182, BPA will be funding several new and ongoing pedigree analyses on populations of listed species. It would be helpful to review this and other similar research and indicate when results can be expected. Such information would inform decision makers on questions of if or when viability analyses using $\lambda$ should be relied upon for ESA reviews.

The paper should categorize populations in the 12 listed ESUs into each of the four categories ("scenarios") listed above. This will allow us to determine which studies are most relevant to the various populations treated in the BiOp.

However, the paper does include a similar discussion on the likelihood that future generations of salmon and steelhead derived from at least one hatchery-origin parent may regain absolute fitness as they adapt to their habitat. Natural selection will be exerted on offspring arising from hatchery-origin fish spawning in the wild. The rate of this natural selection is not known, but could be at least as rapid as the adverse, unintended selection that occurs in an integrated recovery program conducted from a hatchery.

When designing and parameterizing productivity models for natural populations with co-occurring hatchery-origin and natural-origin fish, a range in relative reproductive success should be included that considers increases in fitness of future generations of fish with hatchery-origin ancestors. This expected increase in fitness should be both relative and absolute.

Lambda requires adult-to-adult reproductive success, but most of the studies reviewed in this paper do not measure this quantity (see Table 2 and associated discussion, below), rather they focus almost entirely on juvenile survival. Given the lambda focus (which requires effectiveness at producing adult progeny), and the fact that reproductive fitness at producing juveniles seems to be a poor predictor of success in producing adults (p. 7 2nd para.) some justification for including juvenile-focused studies is needed. Similarly, measures of the precision of effectiveness estimates is needed, and studies with no precision estimates should be down-weighted in the comparisons.

Moreover, estimates of $\lambda$ require relative constancy across generations, or, at the very least, consistency, to be viable; whereas we suspect the opposite to be true for empirically based estimates of hatchery effectiveness in the F2 generation, and across differing spawner densities. More generally, it appears unlikely that hatchery effectiveness will be a constant over time, even for a single stock, let alone multiple stocks, as is assumed in the BiOp. Thus far we are aware of few documented studies of this characteristic, with the possible exception of anecdotal level information presented without error estimates. In the author's view, which of these studies is really relevant to the estimation of lambda?

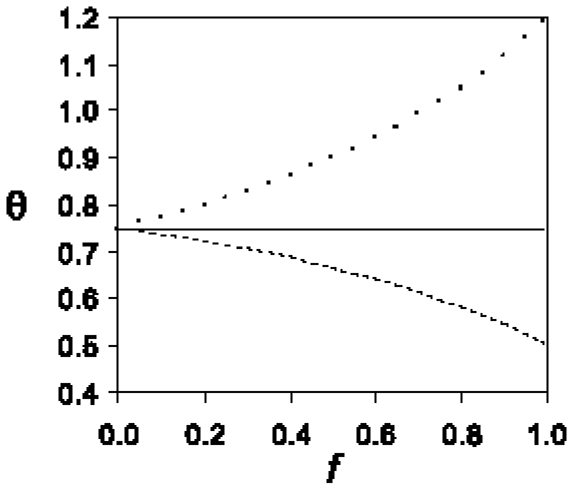
**Adulthood, Origins & Reproductive Success**

Hinrichsen (2003) has demonstrated an expectation that relative reproductive success varies with the mix of hatchery/wild fish on the spawning grounds. Relative reproductive success itself can be inflated owing to supplementation, which can lower the fitness of natural-born spawners (see Eq. 1 and Fig. 1.). The authors should discuss this point since it bears directly on the relevance of the study results to estimating lambda.

(1) $$\theta = \frac{(1-f)\beta_{HW} + f\beta_{HH}}{1-f+f\beta_{WH}} ,$$

*bWH*

where $\theta$ is the relative fitness of hatchery-born spawners, $f$ is the fraction of hatchery-born spawners on the spawning grounds, and the constants $\beta_{WH}$, $\beta_{HW}$ and $\beta_{HH}$ each represent a ratio of recruits per mating (of type WH, HW, and HH, respectively) to recruits per WW mating.




for the increasing, decreasing, and flat relationships between $\theta$ and *f*, respectively. Figure 1. Reproductive success of hatchery-born female spawners, $\theta$, is depicted as a function of fraction of hatchery-born spawners on the spawning grounds, *f*, under different assumptions abut the relative reproductive success of the various crosses ($\beta_{WH}, \beta_{HW}, \beta_{HH}$). When $\beta_{HH} - \beta_{HW}\beta_{WH}$ is positive, $\theta$ increases with *f* (dotted line); when it is negative, $\theta$ decreases with *f* (dashed line); when it is zero, $\theta$ does not change with *f* (solid line). In this illustration, $\beta_{WH} = 0.5, \beta_{HW} = 0.75$ and $\beta_{HH} = 0.6, 0.25$ and 0.375[1]

**Specific Comments or Questions:**

**Pgs. 4-5:** The authors correctly point out that the fitness of a natural-origin population, against which relative fitness of hatchery-origin fish is measured, may itself be lessened by the introgression of hatchery-origin fish in previous generations. A natural population may therefore already have reduced absolute fitness.

**Pg. 6:** There are a number of research projects evaluating the efficacy of "supplementation" that are not included in this paper. Many of these studies are addressing ESA-listed ESUs in the Columbia Basin. It is not clear if these studies did not contain information of importance to the paper, were missed in the review, or if results may be applicable, but not yet available. It would be helpful if the paper included a comprehensive list of research projects on this subject that were considered in the paper's development.

Bonneville performed one such review:"Gaps in Columbia River Basin Research, Monitoring and Evaluation of Artificial Propagation, Reasonable & Prudent Alternatives 182 & 184, 2000 Biological Opinion Federal Columbia River Power System" in January 2003. It is interesting to note that if data from the many supplementation studies were not deemed appropriate for this review, one must question the efficacy of funding such studies.

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[1] Hinrichsen, R.A. 2003. The power of experiments for estimating relative reproductive success of hatchery-born spawners. Can. J. Fish. Aquat. Sci. 60:864-872.

**Pg. 17:** The authors suggest that the results of steelhead and coho research should be applied to stream-type Chinook "…until data on their relative fitness become available." However, previously in the review of the Warms Springs NFH spring Chinook research (pg. 11), the results indicated higher relative fitness from egg – presmolt (0.91). Further, the authors concluded (pg 17) that hatchery-origin spring Chinook "…generally achieved greater relative fitness than steelhead…". The paper should apply the results of the one spring Chinook study to assessments of population viability of spring Chinook. Supplementation of steelhead populations with smolt releases is generally thought to be less successful than for Chinook.

**Pg. 19:** Another application of the effect of competition on reproductive success and model parameterization is that relative reproductive success should be higher when the demographic benefits of hatchery-origin fish are most needed (at low population densities of natural-origin fish) and lower when the demographic benefits of supplementation are least needed (at higher population densities of natural-origin fish).

**Pg. 19:** In the Summary and Conclusions section of the paper, the purpose of the paper is indicated as, "…which is aimed solely at summarizing relative fitness for the purpose of making better estimates of λ for natural populations that contain naturally spawning fish hatchery fish." It would be helpful if this statement of the paper's scope were discussed initially, perhaps under a Purpose title.

**Closing Remark**

Given the stated purpose of the paper, it would be helpful if the authors could reflect on whether lambda should now be used in assessing viability of populations containing varying proportions of hatchery-origin and natural-origin fish given the paper's existing conclusions on the variability and uncertainty in the current knowledge on the relative reproductive success of hatchery-origin fish. Decision makers need to know if the current knowledge about reproductive success of hatchery-origin fish, and its effects on calculations of λ, augers for use of λ based methods.