The Case for Wild Steelhead Recovery Without Artificial Fish Culture Intervention

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Recreational fishing for steelhead trout in British Columbia is world-renowned and in several rivers, cultured fish represent a significant contribution to the catch. The steelhead program of the Freshwater Fisheries Society of B.C., under the direction and policy of B.C.'s Ministry of Environment, and in cooperation with several Federal Fisheries hatcheries, generates hatchery smolts for release. The resultant angling opportunities are of high value to the Provincial economy. The use of hatchery steelhead (*Oncorhynchus mykiss*) and catch and release of wild steelhead provides angling benefits, but may also impose risks to wild stocks. The overall purpose of the Provincial stream classification policy is to manage the risks in order to maintain healthy, self-sustaining wild steelhead stocks. Most rivers with steelhead present in B.C. are classified as wild.

The Provincial stream classification policy may be found at the following web site: http://env.gov.bc.ca/fw/home/steelhead.htm.

In streams where wild fish are relatively abundant and productive, and which offer areas of refugia upstream of the area of hatchery fish release and return (e.g., Kitimat and Chillwack rivers), the policy has proven compatible with wild fish conservation, the priority concern (Heggenes et al. 2006; Nelson et al. 2005; Slaney et al. 1993). In streams with major habitat alteration (e.g., Stave and Capilano rivers), stocking of large numbers of hatchery steelhead smolts provides mitigation for lost opportunities once provided by wild fish that can no longer access historic spawning and rearing habitat.

At what levels of stock abundance is it acceptable to release hatchery steelhead smolts and where should these releases be?

The presence of hatchery returns and restrictive catch-and-release regulations serve to conserve wild fish populations when the recruitment of wild fish is relatively abundant, i.e., in the routine management zone (Fig. 1) by providing marked hatchery fish to harvest and the release of captured wild adults. Further policy precautions in hatchery fish culture and liberation include random selection of wild natal broodstock, and the placement of marked (adipose fin clip) hatchery smolts in the lower portions of rivers. The latter not only focuses the returning hatchery fish into the area of the sport fishery, it also insures that there is less interaction with the wild population, both at release (many smolts fail to migrate, as discussed further below) and in the return (i.e., to reduce the potential reduction in fitness in wild fish when wild and hatchery fish spawn together).

How does stock abundance drive management decisions in steelhead?

The key reference point in the management of steelhead is the "conservation concern threshold" (CCT). For a stock whose recruitment dynamics can be described by a deterministic Beverton-Holt type spawner-recruit relationship, as in steelhead (Ward 2000; Fig. 2) this threshold is approximately 25% of the asymptotic maximum adult recruitment, or carrying capacity. The CCT has the useful property of being largely independent of stock productivity. We further define a limit reference point (LRP) as the spawner abundance from which a stock can recover to the CCT within a defined time (e.g., one generation) in the absence of harvest (Johnston et al. 2002b).

Steelhead populations are very productive at low spawner abundance, where there is little or no density-dependent competition for food and space by juveniles. At the Keogh River, the capacity for smolt yield during the 1980s regime was approximately 6,500 smolts (Ward and Slaney 1988; Ward 1996), and we noted that a few hundred spawners could almost achieve that level of production (Fig. 2). For example, if the population where reduced by some catastrophic event to 10% of its carrying capacity (the conservation concern zone; Fig. 1), or 100 adults at the Keogh River, it would very quickly rebuild naturally, in theory to 60% of capacity in one generation, and almost to its full capacity within the next generation. The latter is dependent on the conditions for smolt-to-adult survival.

Both carrying capacity and productivity can be increased by the presence of marine derived nutrients from salmon carcasses, or through inorganic nutrient addition. Food (invertebrate abundance) increases while the need for space (territory size) decreases. Best results in stream rehabilitation experiments based on steelhead and coho abundance at the Koegh River were obtained from sites where both nutrient levels and available habitat were improved. Steelhead juveniles were larger in treated versus internal and external controls, thus smolt age shifted downward while smolt size-at-age increased, even when juvenile densities were low. There was a positive difference between the smolt yield in the treated watershed and that in the external control (Ward et al. 2002, 2003, 2006 in press). At low spawner densities, an increase in the number of smolts produced per spawner was difficult to detect with statistical rigor, but it is significant biologically that data points after watershed restoration (yellow circles, Fig. 2) were at or above the level of recruitment replacement, whereas they were below it prior to this (1990s, triangles; Fig. 2).

How do steelhead differ from salmon in life history?

Steelhead, unlike salmon, have a highly diverse life history with greater variation in the number of years spent in both freshwater (1 to 5 yrs) and saltwater (1 to 3 yrs), and the ability to spawn repeatedly (usually 10% to 20% of returns are repeats, but it has been higher recently). Steelhead adults return in lower numbers than salmon and over a broader time frame, to spawn in the spring rather than the fall. Survival from egg to fry is higher than salmon, in general. They rear for several years in freshwater, with variation in age structure within and among rivers dependent on the available food and space for these territorial animals. In other words, the carrying capacity for smolt production reaches an asymptote once available rearing space for a given level of production in freshwater has been reached (Fig. 2). Most importantly, a failed year class, due to flood or drought, or poor return of a brood, is quickly made up for by younger and older age classes, such that the age class variation of smolts from a brood may be high, but the total number of smolts remains reasonably constant for a regime of production. Steelhead have overlapping generations, thus reducing the risk of a catastrophic event, compared to the presence of a single year class of low numbers, or compared to the more defined, non-overlapping generations in salmon.

How does culture of steelhead differ from cultured salmon

A major difference in salmon and steelhead culture after release is the failure of some steelhead smolts to migrate and remain in-river as residents, or “residuals”. Both the smallest and the largest fish in the length frequency distribution of hatchery smolts may fail to migrate. Small fish (<13cm) are ill-prepared for smoltification and opt to spend an additional year. Smolts that grew rapidly in the hatchery, particularly males, may prematurely begin the process of maturation rather than smoltification. We have observed that most males in the largest size category may fail to migrate when released in river (Ward and Slaney 1990; Slaney and Harrower 1981). These fish can displace wild parr, consume wild fry, and some even survive the summer and winter to spawn with wild adults. Recently, Walters (2005) noted several internal (e.g., larger spleen, liver, heart, and smaller brain) and external (body shape, fin erosion, head size) morphological and behavioural differences (phenotypic divergence) between residualized hatchery Living Gene Bank (LGB, explained further below) smolts and wild smolts, and tabled several potential life history, demographic, ecological and genetic impacts as a result of residualism. Despite a low-river release, downstream of the Keogh fish fence (blocking upstream migration of these hatchery smolts for several weeks), several thousand of 20,000 to 30,000 hatchery smolts failed to migrate and became resident during summer.

The residualism phenomenon has been observed in other Vancouver Island LGB streams (Quinsam and Little Qualicum rivers), particularly in the spring drought of 2004. Several thousand residuals were observed in these two systems following their release from on-site hatchery rearing facilities. Regional biologists further reported this same behaviour in most rivers where hatchery smolts are released such as the lower Somass, Stamp and Sproat rivers near Port Alberni, and the Seymour and Chilliwack rivers on the Lower Mainland, after releases of hatchery steelhead smolts, at times swamping the wild parr in numbers, leaving little doubt of substantial density-dependent effects on wild steelhead (and others), particularly when wild recruitment is low.

Can hatchery fish speed the recovery of wild populations of steelhead when they are in low abundance?

Little evidence is available to support the contention that hatchery steelhead can serve as a tool to re-build the wild population directly through the spawning of hatchery returns in wild rivers. Indeed, the evidence suggests the opposite may be true. For example, Smith and Ward (2000) provided results from the steelhead harvest questionnaire indicating that the rate of decline of the catch of wild adult returns in rivers with hatchery fish present was greater than that rate in wild-only rivers. Despite the presence of hatchery steelhead in many rivers on Vancouver Island in the 1990s, wild stocks continued to decline, to the point where it was very difficult to locate wild broodstock (thus terminating hatchery releases in these streams). Walters (2005) listed several works where the reproductive success of hatchery fish was lower than wild. Lower reproductive success of hatchery steelhead, and the lowering of reproductive success of wild fish in the presence of hatchery fish, may be attributed to several factors, including morphology, behaviour and genetics. Many examples of factors listing differences between wild and hatchery fish are available in the scientific literature, and there have been several recent reviews.

The distribution and behaviour of hatchery-cultured fish into their natal watershed has been disrupted by the artificial spawning and farming process. Female returns from hatchery releases are smaller and have lower fecundity than in wild fish, automatically entailing lower reproductive success. Wild adults, particularly females, have fidelity in spawning to their family rearing area as juveniles, in general, or have adapted complex behavioural traits that insure survival of the progeny through upstream or downstream migrations of fry or parr. We have observed unique site-specific behaviours of upstream, downstream or off-channel seasonal migrations to refuge or feeding areas that are more likely inherited than learned. That behavioral complexity and fine-scale adaptation is likely altered by the farming aspects of mate selection, the artificial rearing environment, and the release tactics. Returning hatchery fish are unlikely to sort in river according to their family heritage sites, and return mainly to the site of release, thus further lowering fitness compared to wild fish.

Is there a danger to introducing hatchery fish when wild returns are low?

A wild-hatchery interaction model, currently under review and development by Korman and Ward (2006 MS in draft review) as part of a structured decision management process at the Seymour River, suggested that the recruitment of wild fish would be reduced with the presence of hatchery fish. That reduction in reproductive success is less of a concern when wild stocks are within the routine management zone (Fig. 1), but it becomes a greater concern when the adult returns are low (conservation concern), and appears to impede recovery. At the extreme, when wild recruitment is below replacement repeatedly, the model suggested that the hatchery fish will replace wild fish production, such that fish will be present in the system, but at lower abundance due to the lower reproductive success of hatchery spawners from which they may have been derived. This has not been confirmed for B.C. steelhead in the wild.

What is supplementation and why is it risky?

Supplementation, the use of artificially-reared fish to attempt to enhance numbers of juveniles and adults to increase the number of naturally-spawning adults in a target population has been a controversial option for rebuilding salmonid populations for over two decades (ISRP 2005). Supplementation can reduce the natural spawning fitness component in the integrated wild and hatchery spawners, and this reduction in wild fitness will persist for a number of generations after the termination of supplementation, according to the Independent Scientific Review Panel of the Northwest Power and Conservation Council for the Columbia River. In a further report on monitoring and evaluation of supplementation projects, they and the Independent Scientific Advisory Board (ISRP&ISAB 2005) go on to suggest that the critical uncertainties are whether supplementation provides a demographic increase in natural production (the potential benefit) and whether supplementation leads to decreased natural-spawning fitness (the potential harm) in the integrated population. Supplementation entails demographic, genetic (fitness), ecological, and disease risks and uncertainties.

No studies have yet been completed on the question of supplementation in salmonids but several are currently attempting to address the issue with experimentation. The ISRP retrospective report (ISRP 2005) noted that large-scale projects for steelhead trout or chinook salmon are ongoing at the Hood, Yakima, Grande Ronde, Imnaha, Clearwater and Salmon river basins within the Columbia River. The results are not encouraging. The Hood river study in particular is an example where large numbers of residuals, where fish are released at acclimation sites in river, may confound results (Kostow 2004).

A supplementation trial experiment is in process in B.C. As Amman et al. (2004) reported at the Northwest Fish Culture Conference, B.C.'s Living Gene Bank project (LGB) was established in 1998 in response to increasing risks of extinction of steelhead trout populations on the east coast of Vancouver Island. The program was designed to amplify returns while maintaining the wild population's genetic diversity. Wild smolts were selected to represent the genetic diversity of the wild population, transferred to a hatchery (Vancouver Island Trout Hatchery, Duncan), reared to maturity, spawned artificially, and their smolts then released into their natal river. Three Vancouver Island populations (Keogh, Little Qualicum, and Quinsam Rivers) were chosen and the program was conducted on a trial basis.

The LGB project was designed with five years of wild smolt broodstock collection and five years of progeny smolt release to aid the wild population through a single steelhead generation of refuge and amplification during a period of low survival in the ocean. The challenge, yet incomplete, was to assess whether it has been a success in achieving its goal of maintaining genetic diversity and contributing to wild population numbers. The broodstock smolts were determined to be representative of the wild population (Ardren 1999), suggesting that it is possible to adequately sample genetic diversity. However, the application of this protocol is dependent upon adequate infrastructure, intensive monitoring, and historical knowledge of the smolt migration and therefore limits its feasibility for other programs.

Several questions remain as part of the investigation, including domestication selection, skewed family selection, and genetic divergence in returns, and differences in behaviour and morphology. Large amplification of fish numbers from a limited broodstock always carries the risk of genetic divergence from the wild population. In addition, the behaviour of the released smolts and their effect on the wild population remains to be evaluated. Residuals have had negative impact, but it remains to be determined if hatchery returns at the Keogh River will result in an increase in the wild smolt yield, beginning in 2006. Preliminary data from 2-yr-old smolts in 2005 suggested that there was no increase in smolt yield that could be attributed to LGB spawners beyond the values of the 1990s regime, and smolt recruitment was below replacement values (single point, Fig. 2).

Risks and uncertainties remain high in the artificial propagation of steelhead, and many questions remain regarding supplementation, or attempts to use hatchery fish to re-build wild populations. Risks of supplementation must be clearly presented, and weighed against the risk of loss of fitness due to low wild numbers should that occur (these would have to be extremely low in steelhead). It is likely that risks currently outweigh benefits. Investigations on supplementation are necessarily long term (10 to 15 years), such as the LGB work at the Keogh River. Preliminary results to the smolt release and adult return stage, and an early point on smolt recruits from spawners, are not encouraging. At this time the ISRP and ISAB (2005) are not aware of a suitable evaluation of the effects of supplementation on natural spawning fitness of the target population. Addressing an evaluation of the relative fitness of steelhead from supplemented populations compared to unsupplemented populations should be a high priority, but complicated and requiring intensive monitoring (e.g., parentage analysis will require complete sampling of the spawning population in control and treatment streams – difficult if not impossible in the Cheakamus River). Presently, further experimentation with supplementation in B.C. at sites where wild populations have been unnaturally reduced in number, but which will recover rapidly on their own (e.g., Cheakamus River), are not recommended as sites to experiment with supplementation.

Adequate monitoring of returns will assist in determining if Cheakamus River steelhead fail to recover rapidly as expected, at which time the question of supplementation might be revisited. The magnitude of the reduction in adult spawner numbers resulting from a loss at an earlier life stage is not likely to be great enough to threaten the resiliency of the population, but monitoring of returns will assist the decision process. Furthermore, it remains to be seen if juvenile recruitment from nearby areas (e.g., Brohm Creek) will assist. Meanwhile, there are other ways to mitigate for lost recreational opportunities or other compensation requirements.

In summary, the relative risk of employing hatchery fish as a conservation tool appears high in comparison to allowing natural recovery. The latter appears entirely possible and relatively rapid for a productive stock where habitat remains more-or-less intact and relatively productive. The Province should provide further stock and habitat protection and improvements where possible to further improve natural recovery during this time, and consider mitigation for lost recreational opportunities by perhaps increasing the release of hatchery smolts elsewhere. Key to the recovery and habitat protection is the prevention of any further man-induced catastrophe and negative impact.

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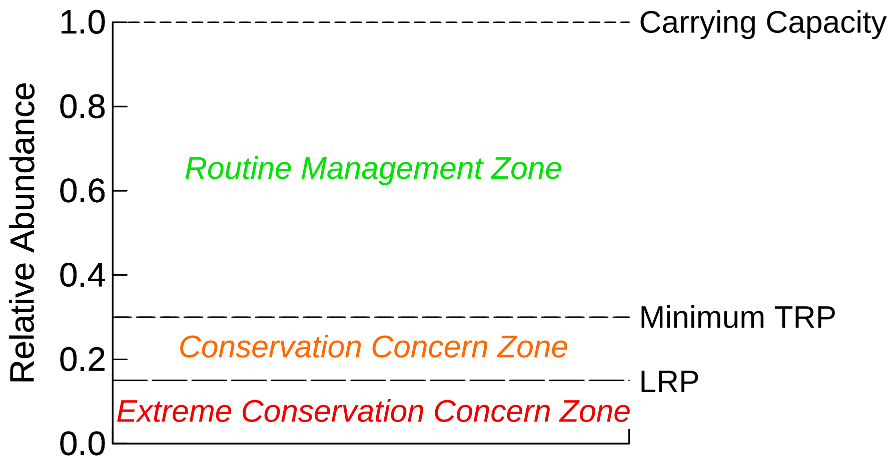

Figure 1. A management framework that uses reference points defined in terms of steelhead abundance results in three distinct management zones with different management objectives and actions. The carrying capacity is the asymptotic maximum recruitment. TRP and LRP are target and limit reference points. The locations of the minimum TRP and LRP here are for illustrative purposes only (from Johnston et al. 2002b).

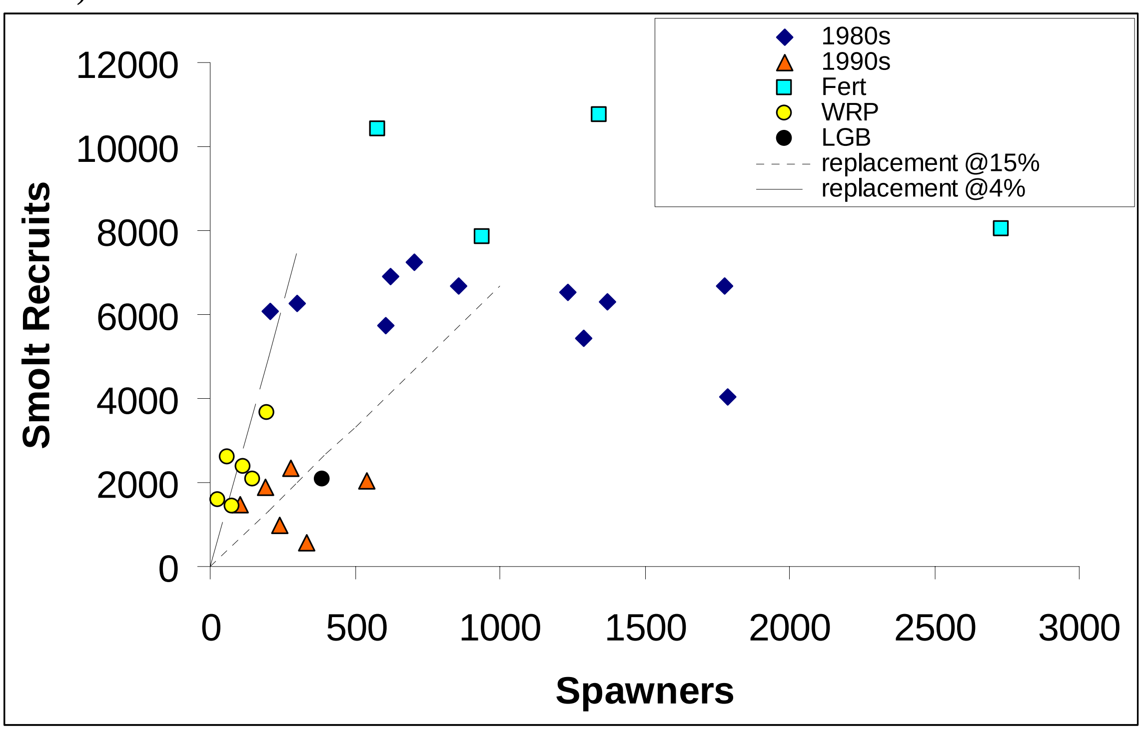

Figure 2. The relationship between the number of spawners returning to the Keogh River, B.C., and the subsequent smolt recruitment during the 1980s regime (diamonds), years of nutrient addition (squares), during the 1990s regime (triangles), after the period of watershed restoration (circles), and a preliminary point from LGB spawners. Straight lines represent the recruitment replacement if smolt-to-adult survival averaged 15% (as in the 1980s; dotted line) or averaged 4% (1990s and on; dashed line). From Ward et al. (2006 in press).