Evaluation of Alternative Recovery Strategies for the Cheakamus River

Final Report submitted to

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Executive Summary

Details on two fundamentally different recovery plans were examined to determine which option might be more effective in restoring the Cheakamus River steelhead population partly decimated by a chemical spill in August 2005. The so-called ‘natural recovery’ plan should allow the population to recover over time without hatchery supplementation. Well-planned habitat improvements should help the recovery process, and at a minimum, provide some protection from further impacts. This natural recovery plan is in agreement with the sound, and scientifically-based provincial government policy concerning the management of steelhead bearing streams.

The alternative recovery plan proposed relies on a short-term hatchery supplementation of the steelhead population during 2007-2008. This plan may reduce the likelihood of a substantial loss in genetic diversity and accelerate the recovery process. There is considerable uncertainty about the speed of the recovery associated with each option. Under some conditions, simple deterministic projections suggest that the recovery period associated with the hatchery supplementation plan may be shorter than that associated with the natural recovery plan. However the natural recovery period may take 10 years or more, or at best a few years more than via hatchery supplementation under favorable environmental conditions.

Based on scientific grounds only, I cannot state categorically, after only a brief and largely qualitative assessment of the merits of both options, that one is definitely less risky than the other, to the long term health of the steelhead population. In the present context, there is considerable support by stakeholders for the hatchery supplementation program mainly to shorten the recovery period, and minimize the socio-economic impacts caused by a reduction in adult steelhead abundance in a river that supports a catch-and-release fishery. Based on socio-economic considerations, the Minister of Environment might consider making an exception to the government policy concerning the hatchery supplementation of wild streams. An in light of the somewhat unique nature of this kind of impact, the Minister of Environment may consider amending the existing policy to deal effectively with similar cases in the future. Should a short-term hatchery supplementation program be allowed to proceed, there appears to be little time left in 2006 to obtain all the Cheakamus River brood stock by conventional means (via angling). However, collecting brood stock from the Squamish River should be considered for 2006 and 2007, and be used for stocking purposes if genetic analyses fail to detect significant differences between fish taken from each river.

1. Introduction

On August 5th, 2005, a Canadian National (CN) railway train derailed near a bridge over the Cheakamus River, with several cars falling in the canyon below. One car filled with sodium hydoxide released about 41,000 liters into the Cheakamus River. As the chemical flowed downstream, it killed thousands of fish, including coho, pink and chinook salmon (*Oncorhynchus sp.),* dolly varden (*Salvelinus malma*), cutthroat trout (*Salmo clarki*)*,* steelhead trout (*Onchorhynchus mykiss*), sculpins (*Cottus sp*.), lamprey (*Lampetra sp.),* and stickelbacks (*Gasterosteus sp.)*. It is thought that most anadromous bull trout (*Salvelinus confluentus*) and chum salmon (*Oncorhynchus keta*) had left the river when the spill occurred.

McCubbing et al. (2005) provide a detailed description of spill, the survey procedures used to assess the impact, and the survey results. The authors estimated that 90% of the fee-swimming fish in the river were killed by the spill, including steelhead in the 0-4 age groups. Steelhead lost will not grow, mature and return to the river so the spawning populations during 2009-2010 might be very low, catalyzing some concern over the populations ability to recover within a reasonable time frame.

Following this incident, several committees were set up to determine the best course of action to restore the aquatic community to its 'normal state'. Biologists from the Canadian Department of Fisheries and Oceans (DFO) opted to help rebuild the salmon populations via hatchery supplementation, although it is not clear if consideration was given to the potential impact of this activity on other fresh water species and the aquatic community supported by this river. Biologists from the University of British Columbia (UBC) also proposed that hatchery supplementation be conducted to help the steelhead population recover more rapidly. By contrast, biologists from the BC Ministry of the Environment (MoE) propose that this population be allowed to recover naturally without hatchery supplementation. During the past few months, there has been considerable debate over the best course of action. On March 30, 2006, following a request by MoE officials, I attended a 'Press Conference' at the UBC Fisheries Center to hear the details of a recovery plans. I was then asked to provide a report by April 30, 2006 containing

- an evaluation of the impact of the spill on the sustainability of the Cheakamus system relative to that of other man induced and natural events, as they relate to steelhead
- a summary of the risks and benefits of the hatchery supplementation versus the natural recovery options
- some recommendations on further stock and habitat protection and improvements that could improve the natural recovery.

Background material to assist with this review was to be obtained via (i) discussions with the UBC and MoE scientists, (ii) meetings with stakeholders in Vancouver, Squamish and Whistler, (iii) a review of the pertinent literature, (iv) an inspection of key sites on the Cheakamus River, and (v) a tour of the Tenderfoot hatchery located near the Cheakamus River. These tasks were completed with some difficulty within the relatively short time frame allowed. Meetings were attended on a scheduled and/or opportunistic basis, and nearly all documents supplied by the proponents of each plan were examined. It should be emphasized that stakeholders as well as MoE and UBC scientists provided considerable assistance for this review, which was most appreciated. What follows is a brief account of the pertinent facts, findings, and conclusions of the review.

2. Relative impact of the CN spill on the Cheakamus River

This CN spill had a short term impact on the Cheakamus River habitat, since most of the chemical was flushed out by discharge within days of the spill. However, the spill caused a severe impact on the aquatic community. As opposed to typical impacts caused by excessive exploitation on specific runs, or human impacts causing the lost of some habitat, the impact of this spill is less selective as it simultaneously affected a large number of species, comprised of several year classes and age groups. Consequently, it may take several years for the aquatic community to regain its natural equilibrium. This is not a major catastrophe like the Hell's Gate rock slide, with some stocks almost completely annihilated. It is also not akin to a major chemical spill that would have contaminated or obliterated that river for years to come. It is simply an unfortunate accident, with short term potential losses of several hundred steelhead spawners in 2009-2010, and potentially other long-term repercussions beyond then. Granted, this population is perceived to be important by many stakeholders (as others are), and there are shared concerns over the best course of action to take. But in my view, this situation hardly justifies the strong reactions heard during the meetings and the UBC Press Conference. After all, some species were not severely impacted, others are being supplemented to speed up the recovery, the catch and release fishery is still open during 2006, and opportunities for habitat improvements are being considered.

3. Details on the hatchery supplementation plan

Few details were provided on this plan during the UBC press conference. Pertinent details were largely obtained during subsequent discussions with Josh Korman, Howard Bailey, and Peter Campbell.
Mr. Korman has been conducting surveys in this river for several years, knows it well, is largely responsible for the hatchery supplementation proposal put forward, and for forecasting the recovery times under specific set of conditions. Briefly, the steelhead brood stock acquisition objective for 2006 amounts to 20 females and 20 males each year. Given an expected escapement of about 400 adults, it is assumed that removing 10% of these would cause little harm to the genetic make-up of the population. Natural production is assumed to be 30 smolts per spawner (not female). The maximum habitat rearing capacity is not known with certainty, but is thought to range from 400 to 730 steelhead smolts per km. Given 15 km

of rearing habitat, maximum smolt production ranges from about 6000 to 11000 smolts. These figures suggest that the number of natural spawners required for maximum smolt production is ≈ 200-350, so removing <10% of them for brood stock would likely not compromising natural production.

Initial plans were to collect adults before the end of the first week of April, because some spent adults (kelts) start leaving the river as early as mid-April. The most recent snorkel surveys conducted in this stream on April 5, 13 and 20, 2006 revealed the presence of 52, 44 and 44 adult steelhead respectively. These counts are expanded to account for detection rates (function of discharge and visibility), so it is estimated there were about 175, 122 and 161 adults on these occasions respectively. On the last two surveys, some redds were observed, some fish appeared to be paired for spawning, and some anglers reported catching kelts in the lower reaches, so the spawning season has started. More adults are expected to enter the spawning areas in the weeks to come. Those with considerable steelhead angling experience on this river claim that the escapement estimates based on snorkel surveys are lower than the true escapements, because surveys cannot be conducted during the late spring freshets, during which the bulk of the spawners move in. Anglers report catching ripe females until the 3rd week of May. In light of such facts, there seems to be still time to collect brood stock, but the window of opportunity may shrink rapidly beyond the 4th week of April. Furthermore, as time goes by, it is less likely that the brood stock obtained will consist of fish that compose the early, mid, and late part of the run, which would be preferable so as to not favor a particular segment of the run.

It is proposed that ripe adults be captured using volunteer anglers with considerable experience. These would then be taken to a public hatchery for processing. Mr. Korman estimates that each female or adult pair taken for brood stock can produce 1500-2000 pre-smolts in a hatchery environment. With 20 pairs, some 30,000-40,000 pre-smolts could be produced, and be available for stocking purposes. A more conservative estimate based on an average fecundity of 2000 eggs per female, coupled with a 65% egg-to-smolt survival, suggest that perhaps only 20,000 pre-smolts would be produced. In any case, after 11 months of growth in the hatchery, some pre-smolts would be released in the Cheakamus around May-June 2007-2008. It was initially assumed that the first generation hatchery fish (F1 progeny) could attain 60-80 grams before release, which is roughly the size of the most predominant wild smolt age group (3+) leaving the Cheakamus River (C. Melville, pers. comm.). So it is hoped that 11 months of hatchery rearing can replace two years of natural growth in the stream. The pre-smolts to be released in 2007-08 would simply replace those from two year classes killed during the spill, and in turn, accelerate the recovery.

Accelerated growth can be obtained by providing optimal conditions that include increased water temperatures relative to those of the natural environment. Initially it was suggested that fish might be reared in the Fraser River Valley hatchery because the water temperatures used for rearing are higher than those in the Cheakamus River. However, salmon reared in a distant hatchery, supplied with a different water source, tend to exhibit higher straying levels than their natural counterparts. Ideally, the water used to supply the hatchery should come from stream of origin, or at a minimum from the same watershed, so as to minimize disruption of the imprinting process. Upon further inquiry, it was learned that the water used for rearing purposes at the Tenderfoot hatchery has a temperature roughly the same as that of the Fraser River Valley hatchery, because both hatcheries use re-circulated groundwater for rearing purposes. The Tenderfoot hatchery is supplied with well water, taken from an area adjacent to the Tenderfoot lake, which flows into Tenderfoot Creek, and then into the Cheakamus River. The water is re-circulated within the hatchery, and can be maintained within 8-11^{o}C. The hatchery manager confirmed that the DFO was willing to provide assistance and support to rear steelhead (if requested by the MoE). The hatchery has not experienced serious disease outbreaks in the past, has sufficient space to hold >100,000 eggs and can easily rear the progeny up to the 60-80 g in concrete raceways. Thus, if hatchery supplementation is to be conducted, the Tenderfoot facility seems to be a suitable choice.

All hatchery reared fish would be fin-clipped (adipose removed) while in the hatchery to distinguish these from wild fish, and help conduct future assessments. To ensure that the total number of smolts leaving the river is not much greater than maximum natural production, the number of pre-smolts released would be determined after accounting for the hypothesized lower ocean survival rate of hatchery smolts relative to that of wild smolts (assumed to be roughly half). Hatchery pre-smolts would then be released at a time and place that would not interfere with the natural migration pattern of the wild smolts, possibly using a side channel in the lower reaches. After a short acclimatization period, these would migrate to sea, and return after 2 years of ocean life to spawn in the system and complement the natural spawners. Hatchery reared winter run steelhead tend to return closer to the rearing site than the release site (Nelson et al. 2005). Since the release and rearing sites are the same, angler-based surveys (ideally via LEH, with mandatory reporting) could be conducted eventually in the lower Cheakamus River to assess the success of the program, given that recent surveys have shown that over two-thirds of the wild adults spawn below the Tenderfoot hatchery (J. Korman, pers. comm.).

4. Details on the natural recovery plan

Hatchery supplementation of wild steelhead stocks is currently not favored by the MoE biologists, and Ward (2006) provides some of the underlying facts supporting this view. It is assumed that the Cheakamus River steelhead population will recover naturally over time because it is composed of several overlapping generations. Steelhead may rear in this river for 1-3 years, and then spend 2-3 years at sea before returning to spawn. So spawners usually include a mix of life history types with *x* years of stream life and *y* years of ocean life. Using decimals to denote ocean years, this spawning population may include ages 2.2, 2.3, 3.2, 3.3, 4.2, 4.3, so 4-7 years in total age. The most common age groups are thought to be 3.2 and 3.3; three years of stream life followed by 2-3 years of ocean life, so spawners are mostly 5-6 years old. The 2005 spill is thought to have killed a large portion of the 0-3 steelhead age groups in its path, so one would expect reductions in escapements during 2007-2010.

Some steelhead were at sea during the spill. Some of these should return to spawn and slowly rebuild the depleted year classes over time. Some of the progeny of fish that spawned naturally since the spill will also return to spawn in the river. Alevins, fry and par occupying Brohm Creek (a Cheakamus tributary) were not killed by the spill, as well as some embryos still in the Cheakamus River streambed during the spill. Fry and par holding in the Cheakamus River side channels and back water areas that were not contaminated also survived. And some adults returning to the Squamish River may stray into the Cheakamus River to spawn there as well. So a substantial number of steelhead may return to spawn during the years of concern, although perhaps much less than would have returned had no spill occurred.

In light of such facts, there seems to be a general consensus among all the people met, and among the attendees of the UBC press release, that the population will recover naturally, at least in the absence of another major impact. The main question is how long will it take for the steelhead population to return to a normal state. Proponents of the natural recovery plan claim that steelhead are very productive at low levels of abundance. Ward (2006) draws attention to this fact using specific cases, and claims that natural recovery can occur rapidly. Even an examination of the escapement time series presented by Mr. Korman shows that the relatively low escapements (100-300 adults) of 1995-2000 were followed by high returns in 2001-2004, which supports the hypothesis that relatively high spawner:recruit ratios are associated with low spawner densities. So low runs in 2009-2010 might produce relatively large returns in less than 10 years. Furthermore, the populations of natural predators (sculpins, bull trout and cutthroat trout) were also negatively impacted by the spill, so predation rates may be much lower than historically. This would further improve the productivity of natural spawners, given the increased survival rate during the fresh water stage.

Proponents of the natural recovery plan also suggest that habitat improvements be conducted to help the population recover more rapidly. This option has been criticized by UBC scientists, who claimed that the BC government spent $1 million to improve the Keogh River habitat, with no evidence of increased productivity. This claim seems a bit exaggerated, with little data provided to back it up. It is a well know fact that the detrimental impacts of some logging practices may take several years to reveal themselves (Scrivener and Brown, 1993). Similarly, the benefits of some habitat restoration activities are not always immediate, and may also take years to reveal themselves (Koski, 1992). Increased fish productivity in the stream may be masked by unaccounted increases in exploitation, worsening ocean conditions, and other factors, so conclusions based on a simple examination of time series of escapement indices may be misleading. In a recently published peer-reviewed scientific publication, Ward et al. (2006) evaluated the success of habitat restoration activities on the Keogh River, and concluded that they had positive impacts on steelhead productivity per spawner. Many other studies have demonstrated the positive impacts of habitat improvements on salmonid populations (for instance see Solazzi et al., 2000, Roni and Quinn, 2001).

Granted, not all forms of habitat improvements are equally effective, so proper planning must be conducted based on the characteristics of each stream and the species assemblage supported. During various discussions, several types of improvements were proposed for the Cheakamus River. These included stream fertilization, create new side channels, improve existing ones, adding large woody debris (LWD), removing barriers to the upstream migration (like the concrete slabs under the railroad bridge), and etc. Some consider nutrient additions to be unnecessary, as the river is relatively productive owing to its geo-morphological features, and some nutrient input from the town of Whistler. However, the cost-effectiveness of various proposals is currently being evaluated by a technical committee including representatives of the First Nation, the Squamish District, CN, DFO, and the MoE. The relative merits various types of habitat improvements will not be addressed here. It is simply assumed that the recommendations of the Technical Committee will be sound and scientifically based. It is also assumed that properly planned habitat improvements can definitely help the steelhead population recovery more rapidly. At a minimum, it is hoped that consideration will be given to installing structures near the bridge that would prevent derailed train cars (if any) from falling into the canyon, and creating additional fish refuges to help buffer the populations from the further spill impacts (if any).

It should be emphasized that an important factor supporting of the natural recovery plan is the BC Government policy concerning the management of steelhead stocks and the supporting systems. The "Steelhead Stream Classification" policy was examined with the objective of determining if it contained provisions that applied to the present case. The policy requires all streams containing steelhead to be classified as "wild" or "hatchery-augmented". The Cheakamus River is currently classified as a "wild" system. It was subject to some fry stocking during 1983-85, but the policy states that "historic stocking of hatchery fish does not preclude the wild designation". The policy stipulates that wild steams are managed to maintain and protect the abundance, distribution, and genetic diversity of steelhead stocks. Basically no hatchery augmentation is allowed in wild systems. When a wild population has declined considerably, the policy stipulates that management priorities should focus "first and foremost on restoring stock abundance through improved stock management and/or habitat protection, habitat improvement, or enrichment of natural habitat", and "in no case will hatchery-augmentation be considered as a substitute for habitat protection and restoration".

The policy allows a stream to be re-classified as hatchery-augmented, "if it has been impacted to the point that [natural] recovery is not considered possible". This is not the case for Cheakamus River, as natural recovery is considered likely given due time. Should this view change, a stream re-classification request can be submitted to the regional manager for evaluation by the MoE Anadromous Fisheries Committee, which can forward it to the Environmental Stewardship Division Management Committee for a final decision. So there is a procedure available to deal with cases where there is serious concern over the state of a steelhead stock. The BC Government policy also allows for “Conservation Fish Culture” programs, which are specialized and experimental forms of hatchery intervention designed to prevent the extinction of the population and conserve genetic diversity. However, the requirements for a “Recovery Plan” must be met, in accordance to the *Species at Risk Act*, and the Accord for the Protection of Species at Risk. In the case of the Cheakamus River steelhead population, some age groups were severely impacted, but this is not a ‘species at risk’, nor is it a ‘stock at risk’, otherwise the current catch-and-release fishery would surely be closed. In light of such facts, it seems abundantly clear that the recovery plan supported by the MoE biologists is in agreement with the current policy, as it should be.

The natural recovery plan has been criticized by some as being equivalent to “doing nothing”. An alternative viewpoint is that monitoring how this population responds naturally to a serious perturbation can provide valuable information that may help deal with similar situations in the future. This is not akin to doing anything, but rather learning about the system by deliberately limiting further human intervention.

5. Pros, Cons, Benefits and Risks

Discussions with various stakeholders, user groups and concerned citizens revealed an overwhelming support for a short-term hatchery supplementation program. Details on the feedback received are provided in the Appendix, as it is not the focus of the present report. Suffice to say, most of those contacted shared concerns about the possible negative impacts of sustained hatchery supplementation of wild stocks, and support the current BC government policy. However, this accident is perceived as somewhat of a unique type, with considerable long-term repercussions on the well being of community members who benefit directly and indirectly from the Cheakamus steelhead population. A two-year hatchery supplementation program is perceived by many as being essential to restore the abundance of the steelhead population within the shortest time frame.

Proponents of the hatchery supplementation plan also emphasize it is needed to ensure that this population is buffered from the potential long-term impacts of genetic drift. It is argued that the number of spawners returning in 2009-2010 could be too low (say <50) to maintain the genetic diversity of this stock. This is a plausible hypothesis, and a genuine source of concern from a biological perspective, as it may affect the ability of this population to cope with environmental changes and perturbations, and recover numerically in the future. This issue is linked to the concept of minimum conservation requirements. Ensuring the minimum requirements are met is priority according to the Federal Fisheries Act. Minimum requirements have been set for a few salmon stocks, largely using ‘rules-of-thumb’ based on genetic studies, but scientifically defensible figures are not yet available for BC steelhead stocks or stock aggregates using a watershed. In the absence of stock-specific figures, MoE biologists recently proposed a conceptual framework for managing steelhead populations in BC (Johnston et al. 2002). This proposal uses abundance-based biological reference points to categorize the state of a population, and the associated set of actions that might be considered to facilitate the recovery of a depressed population within a given period. The proposal states that when a population is reduced to about 15% of its carrying capacity, it enters the Extreme Conservation Zone, and “extraordinary measures” might be considered to increase productivity. Such measures include, but are not limited to, hatchery supplementation. This conceptual framework has not yet been incorporated into the current BC government policy, but it does highlight a shared concern by some MoE biologists over the best course of action to take when a population is in a very depressed state. The conceptual framework also draws attention to actions that may required to deal with abnormal situations (major accidents), an issue that is not well addressed by the current government policy.

In the above context, the so-called ‘carrying capacity’ level is the asymptotic [average] maximum recruitment level produced by a Beverton-Holt stock-recruitment model. For the Cheakamus River steelhead population, this level has not been set. Historical trends indicate that up to 2000 steelhead spawned in the river, but this figure can be considered as a high point of a log-normal distribution centered on the average maximum recruitment. MoE estimates of capacity based on old habitat reports are about 700 adult steelhead given a 13% marine survival rate, that is considerably higher than the rate currently used for forecasting purposes (G. Wilson, MoE, pers. comm.). Using this figure as the carrying capacity suggests the upper limit of the Extreme Conservation Zone would be about 105 spawners. The 2009-2010 adult escapements may be lower than this. If the conceptual framework was part of the existing policy, one might consider implementing a short-term hatchery supplementation program to ensure that spawner abundance levels do not fall below some critical threshold value, to prevent the likelihood of facing a ‘genetic bottleneck’, and cause the recovery process to be excessively long.

There is little doubt that hatchery supplementation can translate into greater returns, but is it an effective means of rebuilding a wild steelhead population?. Proponents of the hatchery-supplementation plan claimed so, citing cases from the Sacramento River and the Hood River. A cursory review of the supporting documents was conducted to verify this claim. During July 1991, a train derailed off a bridge in California, and a chemical tank car ruptured and spilled liquid in the upper Sacramento River (see http://www.cantaratrustees.org/reports/1996/96report). This incident, termed the “Cantara Spill”, killed thousands of fish. Stocking of hatchery trout into the river and its tributaries was suspended to permit the recovery of food organisms. Hatchery supplementation started 18 months later, but the effectiveness of this program was disappointing, and angling was only allowed 3 years later. As for the Hood River case, Blouin (2003) conducted a pedigree analysis and concluded the average fitness of hatchery winter run females during three consecutive brood years (‘95/96, ‘96/97,’97/98) was about 93% of that of natural fish. For males, it was about 88%. In a subsequent “progress report”, Blouin and Araki (2005) re-analysed historical data and claimed that hatchery supplementation during the 1990s provided a short term demographic boost to a wild population, with no obvious negative genetic consequences. And in a recent review of hatchery supplementation practices in the Pacific Northwest (HSRG, 2004), two cases were cited as successful steelhead hatchery programs (Hamma Hamma and Wynoochee River winter steelhead), but no data were provided to show that the programs succeeding in restoring wild stocks.

In British Columbia, hatchery fry and par have been released in many Fraser River tributaries over the years (Chilliwack, Chehalis, Alouette, Coquihalla, Kanaka, Brunette, Stowe, Bonaparte, Deadman, Nicola, Bridge, Chilcotin, etc.), but there is still no solid evidence that these systems benefited or suffered from supplementation (Anon., 1998). One long term hatchery supplementation program of the wild steelhead population in the Kitimat River, using brood stock from the same river, was shown to have little impact on the genetic structure and variation of the population, except for a possible reduction in rare alleles (Heggenes et al. 2006). So none of the above cases demonstrate conclusively that hatchery supplementation can definitely help a wild stock recover from a depressed state. Interestingly, the 1980 eruption of Mount St-Helens decimated wild, winter-run steelhead populations in the Toutle River drainage. By 1985, stream surveys confirmed that the population in the south Fork Toutle had recovered considerably without any hatchery supplementation (Lucas, 1985). So given such facts, one cannot conclude that hatchery supplementation is far more effective than natural recovery.

Hatchery supplementation practices have evolved considerably over the past few decades, and the short-term hatchery recovery plan proposed for the Cheakamus River differs substantially from fry outplanting operations as conducted in the past. It is beyond the scope of the present report to summarize all recent developments. But after an extensive review of current hatchery practices in the US in the late 1990s, scientists concluded there is good potential for hatcheries to provide benefits to the recovery of naturally spawning populations. Since then, one scientific committee has focused attention on identifying and improving methodologies specifically for the purpose of restoring and conserving naturally spawning salmon and steelhead population (HSRG, 2004). An important conclusion is that stocking and outplanting of hatchery steelhead smolts [from other watersheds] can pose “unacceptable ecological and genetic risks to naturally spawning populations”. Hatchery operations can affect both the long-term genetic constitution of a population and the short-term and phenotypic performance of the target population. The committee recommended that managers develop a system of wild steelhead management zones, where no hatchery-propagated steelhead is introduced, and which are managed for “wild” steelhead only. This recommendation is in agreement with the current BC government policy. The committee did make a distinction for cases when native brood stock is used for supplementation, but only as part of an integrated stock management plan, which aims to sustain a population composed of artificial and wild fish, at a higher level of abundance than would occur naturally.

Historically, concerns of hatchery supplementation were generally based on (i) the possibility for disease transmission, (ii) competition between hatchery and wild fish, (iii) straying rates, (iv) possible reduction in fitness of the recipient population, (v) possibility of residualism, (vi) predation impacts, (vii) competition for spawning sites. Given details on the hatchery supplementation program proposed, the possibility of (i) is considered minimal because modern and proven practices are currently used in public hatcheries. The possibility of (ii) is also considered minimal because the hatchery-reared fish will not be released as large fry to compete with smaller wild fry, but is to be released as pre-smolts that will not interact extensively with wild smolts. With regards to (iii), straying rates would be minimized by rearing fish at the Tenderfoot hatchery, and by allowing pre-smolts to acclimate for some time in the Cheakamus River. With regards to (iv), even Mr. Korman acknowledged during the UBC Press Release that hatchery fish tend to have slightly lower fitness (reproductive success) than their wild counterpart. However, there is no way to determine if the eventual crossing of F1 hatchery-reared adults and wild adults would lead to a permanent reduction in fitness of future generations (F2+). From a biological perspective, one would assume that without sustained supplementation, fitness would progressively increase to historical levels within a few generations through natural selection.

With regards to (v), this is not a trivial issue, and merits serious consideration. Releasing a relatively large age 1+ pre-smolts in the Cheakamus River could lead many to “residualize”. Basically, steelhead smaller than the average smolt size often remain in the river for another year of growth. Those above average tend to remain in the system to mature and revert back to the resident rainbow trout life form (see Slaney and Harrower 1981). Small fish that residualize are usually <45 grams. Large fish that residualize tend to be predominantly males. Surveys conducted in the Keogh, Little Qualicum and Little Campbell rivers showed that hatchery reared steelhead can exhibit residualism rates of up to 40%, or much greater than those of their natural counterparts.

To reduce the likelihood and potential impacts of residualism (displacement of wild parr, predation on wild fry, competition, etc.), the proponents of the hatchery supplementation plan propose to conduct a ‘volitional’ release of hatchery pre-smolts. Viola and Schuck (1995) described this procedure, but its success rate has been disappointing in some cases (Osborne and Rhine, 2000). The procedure involves using a release site that allows for the removal of fish that residualize. In the Cheakamus River, an existing side channel in the lower reaches could be used for this purpose. Wild fish in a section of the channel would be removed and released elsewhere. Hatchery pre-smolts would then be stocked in a blocked section of the side channel, and given time to acclimate to local conditions. Steelhead that smolt would migrate downstream naturally via some passageway to the river. After the main migration period, those that remain and show no sign of smolting would be removed. Consequently, a substantial portion of the hatchery pre-smolts available might be removed after stocking. Unfortunately, field surveys have shown that not all smolts leaving the release sites actually go to sea, and many remain to rear in areas above the river mouth (P. Slaney, pers. comm.).

High levels of residualism reduce the effectiveness of the hatchery supplementation program, since the progeny of the brood stock taken does not help rebuild the wild population, increases the resident rainbow population and the level of interactions between and among species. One way to reduce the number of fish that do residualize would be to allow for summer fishery to take place when winter-run steelhead left the system. Anglers could thus help with the recovery process by catching and retaining 'fin-clipped' rainbow trout that residualize. This procedure has been used in other BC rivers with some success, but only helps remove residuals one or more years after pre-smolts are released, it cannot prevent all types of interactions.

With regards to predations impacts (vi), there is no reason to believe to believe that a controlled, well-planned release of hatchery reared pre-smolts, possibly combined with an angler-based control of residuals, would cause a large increase in predation pressures on wild juvenile steelhead. As for competition for spawning sites (vii), at this stage, there is no reason to believe this will be a serious source of concern, although it might be advisable to plan surveys to determine if there are differences in spawning habitat utilization between both groups, and evidence of competition.

6. Predicted recovery times

To provide insight on how fast the Cheakamus population might recover under certain conditions, Mr. Korman used a simple mathematical model to forecast the state of an age-structured population using the observed time series of escapements and some population survey results. The model uses a substantial amount of reliable data collected in this river since 1995. This deterministic model relies on several hypothesized values to account for maximum smolt rearing capacity per km of habitat, the number of smolts per spawner, marine survival rates, the fraction of adults that spawn more than once (20% repeat spawner), the proportions of smolts that migrate to sea at age 2+, 3+ and 4+, the proportions of adults that rear in the ocean for 2 and 3 years, and etc. The model can also account for the hypothesized loss of some juvenile in the river due to the so-called 'one-in-a-century' flood during the fall of 2003.

This model has been criticized by government biologists for being overly simplistic. It does not account for stochastic processes; it uses a stock-recruitment function that differs from the Beverton-Holt model often used in this context for forecasting purposes; it fails to account for greater productivity levels at low abundance and density dependent changes in age structures; it relies on parameter values derived from other stocks; it does not account for the potential benefits of habitat restoration work; it does not account for the potential long term impacts of hybridization with hatchery-reared fish with lower fitness; and does not account for potential impacts of high levels of residualism. The model also uses maximum smolt productivity levels that are considered too low and tend to delay the recovery period.

Such model limitations may have a major influence on the predicted trends. However, it should be emphasized that no model is perfect, and some simplifications are often necessary. In the absence of empirically derived parameter estimates from the system under study, one often has little choice but to use parameter values from other periods or systems. The dynamic response of a severely perturbed system cannot be predicted with certainty, especially when there is only a relatively short time series of observations available, and the system has never been subject to similar impacts in the past. Should more time be available, one should modify the model to try to address the above comments, forecast trends obtained with other combination of hypotheses, and conduct some sensitivity analyses to identify the key features that should be given priority in further monitoring plans.

Suffice to say, the model presented by Mr. Korman describes plausible outcomes under a set of conditions, even if it does not account for all the underlying uncertainty, and all the dynamic features of this system. Mr. Korman formulated this model on his own to provide insight on what might happen in the long run. It is somewhat surprising that a UBC graduate student was the only person that attempted to forecast the long term impacts of the spill and the recovery times. Mr. Korman should be commended for his initiative, and for providing a copy of the model to the present author for examination and illustration purposes. The MoE should have a team of stock-assessment scientists with modeling expertise to forecast the impacts of accidents such as these, to help identify the most cost-effective and socially acceptable recovery plan. Such accidents will likely happen again in the future. A quick-response team could help evaluate different options based on the context, for peculiar cases that are not well covered by existing policies. The resources currently available might be insufficient, but this incident highlights the need to determine if adjustments are required.

The predicted trends indicate that under a set of assumptions, in the absence of hatchery supplementation and negative impacts from genetic bottlenecks or other accidents, the steelhead population may require 20 years or so to recover naturally given ocean survival rates of 3.5% (Fig. 1, top). Under the same conditions, but with hatchery supplementation, it may take about 7 years (Fig. 1, middle). Under more favorable ocean conditions (survival 7%), in the absence of hatchery supplementation, the recovery period may be about 10 years (Fig. 1, bottom). Note that this model sets an upper limit to smolt production (considered by many to be too low), and does not allow for the log-normal distribution of returns centered on a mean rate, as is typically assumed when using stock-recruit functions to forecast returns. If the model was modified accordingly, the recovery times might be even lower than the trends predicted under each scenario. The model could be extensively modified in other ways as well, but nobody can predict ocean survival rates, so there will always be substantial uncertainty associated with each projection. Still the different forecasts suggest that under some conditions, the recovery period associated with the natural recovery plan may not be 10 years longer than that obtained via hatchery supplementation.

7. Conclusion and Recommendations

The MoE has a sound, and scientifically-based policy to guide and limit hatchery supplementation of steelhead baring streams. This policy should be consistent and applicable on a province-wide basis. The natural recovery plan proposed by MoE biologists is in agreement with this policy, as it should be. Furthermore there appears to be a general consensus that this steelhead population can recover naturally with time, and without hatchery supplementation. However, the policy does not have provisions to deal with uncommon impacts such as caused by the Cheakamus River spill. The conceptual framework recently proposed by some MoE biologists addresses this issue, and suggests that hatchery supplementation might be considered in cases where minimum conservations requirements may not be met, and there is some long term risk to the population without direct intervention. The MoE is currently engaged in collaborative scientific research programs that focus on hatchery-wild interactions, and genetic impacts of hatchery supplementation, with the objective of determine how best to used hatchery fish to help restore wild populations. However, the results of ongoing investigations are not yet available to provide guidance, and revise the existing policy.

The hatchery supplementation plan proposed by Mr. Korman and his colleagues seems reasonable, and may substantially reduce the recovery period. More important is the fact that it may limit the impact of a possible genetic bottleneck that could occur in 2009-2010 should the number of spawners returning to this river be extremely low (<50). Unfortunately, at this stage, one cannot predict with certainty what the ocean conditions will be, how many adults will return to spawn in 2009-2010, and what the benefits of habitat improvements will be. In fact, even the proponents of the hatchery supplementation program admit openly that “there is no guarantee that hatchery supplementation will dramatically speed the recovery rate of the Cheakamus River wild steelhead population“ (Korman et al. 2006). Consequently, one cannot determine with certainty how long it will take for the population to recover with or without hatchery supplementation.

The risk to the long term health of the steelhead population in the absence of hatchery supplementation should not be overlooked, nor should it be exaggerated. Even if a very low number of spawners in 2009-2010 lead to a substantial reduction in genetic diversity, it should eventually recover due to the input of other year classes from overlapping generations. At this stage, the period required cannot be predicted with certainty. Hatchery supplementation may not be needed, but could likely produce higher returns in 2009-2010. The long term impact of this hatchery supplementation program via residualism, increased competition, loss in fitness, and so forth cannot be overlooked, nor should it be exaggerated. At this stage, all negative impacts (if any) cannot be predicted with certainty. There is also little evidence to that past hatchery supplementation helped restore wild steelhead stocks. However, the proposed plan is based on modern rearing and stocking practices, and would be carefully controlled if implemented. There is no reason to be overly pessimistic, and assume the Cheakamus River steelhead population will sustain long-term permanent damage from a short-term well-managed hatchery supplementation program, using brood stock from the same watershed.

Based on scientific grounds only, I cannot state categorically, after only a brief review, that one option is definitely less risky than the other to the long term health of the steelhead population. It also seems obvious that some form of habitat improvements may benefit the entire aquatic community, help compensate for the past habitat loss, and even help buffer the community from further incidents. Given this largely qualitative assessment of the risks and benefits associated with each option, the natural recovery plan should be preferred if the impact had been less severe, or if the steelhead population was in a more isolated part of the province, with no nearby community deriving direct and indirect benefits from a quick recovery. In the present case, there is considerable support by stakeholders for the hatchery supplementation program mainly in the hope of shortening to recovery period, and minimize socio-economic impacts. It would thus appear that a political decision is required to deal with this issue. Given context-specific socio-economic considerations, the Minister of Environment might consider making an exception to the policy concerning the hatchery supplementation of wild streams to allow for the possibility of a faster recovery. The public might see this as a precedent setting decision that justifies hatchery supplementation in all cases where steelhead populations are negatively impacted. So if this option is chosen, the MoE should emphasize that short-term supplementation is only allowed to deal with an exceptional case, and that long-term supplementation is still not considered to be a viable option for rebuilding depressed steelhead populations.

Should be MoE allow the short-term recovery plan to proceed, there may be little time left to collect brood stock in the Cheakamus River during 2006. If it is too late, the MoE might consider only allowing hatchery supplementation plan to start next year, after more preparation and better planning. Also if the so-called ‘once-in-a-century’ flood of 2003 did reduce the juvenile steelhead population considerably, there may be even fewer spawners in 2007 than in 2006, which might make it more difficult to justify the removal of 40 adults for brood stock collection. It might be advisable to consider taking only half of the brood stock target each year from the Cheakamus River, to reduce the impact of the brood stock collection activities on the natural spawning population. The other half might be obtained from the

Squamish River. After all, the Cheakamus River flows into the Squamish River, and there is likely regular genetic exchange between the two populations each year via low level straying. So brood stock should be taken from each river, and if genetic tests reveal little or no difference between the two groups, it is recommended that the progeny from both groups be used to supplement the Cheakamus River in 2007. Should the returns to the Cheakamus River in 2007 be too low to justify brood stock collection, then all the brood stock should be obtained from the Squamish River. In such case, it would also seem advisable to close down the catch-and-release fishery during 2007 to minimize further impact on the few spawners in the system, and keep the fishery closed beyond this period until there is evidence to indicate that the population can support a catch-and-release fishery.

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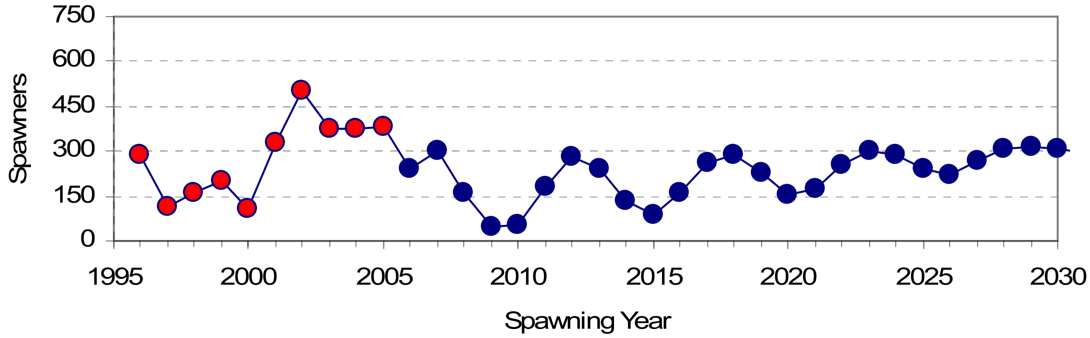
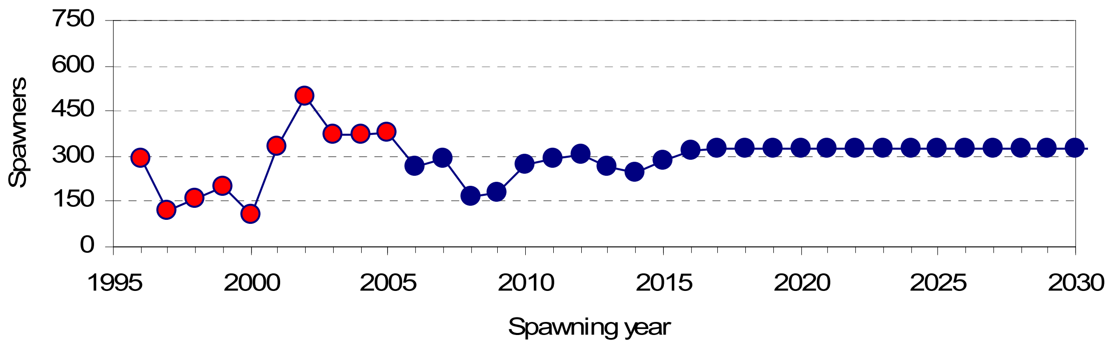
FIGURES





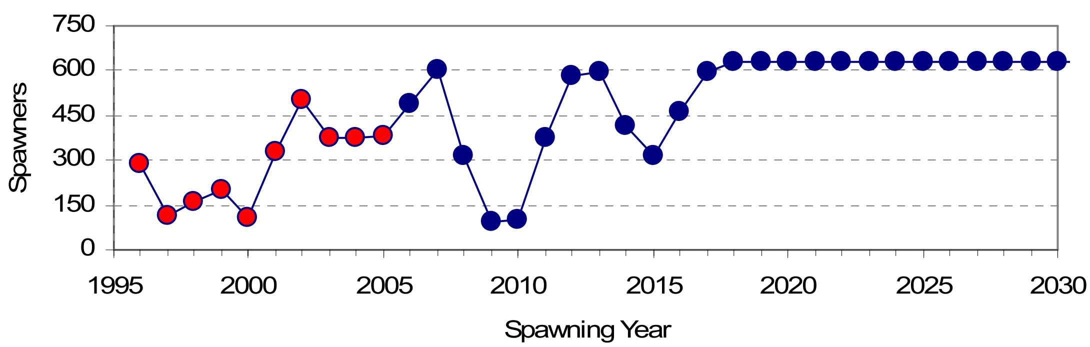


Figure 1. Time series of steelhead spawning abundance in the Cheakamus River for three hypothetical scenarios. Red and blue dots respectively represent observed and predicted abundances. Top trend represents natural recovery pattern with marine survival rate (smolt-to-adult) of 3.5%. Middle trend involves hatchery supplementation, under the same marine survival rate. Lower trend represents natural recovery with a marine survival rate of 7%. Trends computed with the same parameter and equations used by Mr. Josh Korman for illustration purposes. Figures reproduced with the permission of Mr. Josh Korman.

APPENDIX. Summary of meetings and discussions.

Persons met and/or contacted

The Honourable Barry Penner, Minister of Environment
Dr. Ken Ashley. Greater Vancouver Regional District
Dr. Howard Bailey. Nautilus Environmental
Mr. David Brown. Squamish-Lillooet Sport Fish Advisory Committee
Mr. Aaron Bruce. Ratcliff & Company LLP
Mr. Peter Campbell. Tenderfoot Hatchery
Mr. Bran Clarke. BC Ministry of the Environment
Mr. Carl Halvorsen. North Vancouver Outdoor School
Dr. Tom Johnston, BC Ministry of the Environment
Mrs. Franchesca Knight. District of Squamish
Mr. Josh Korman. University of British Columbia
Mr. Randall Lewis. Squamish Nation.
Mr. Al Martin. BC Ministry of the Environment
Mrs. Caroline Melville. Instream Fisheries
Dr. Marvin Roseneau. British Columbia Institute of Technology
Mr. Patrick Slaney. PSlaney Aquatic Science Ltd.
Dr. Eric Taylor. University of British Columbia
Mrs. Edith Tobe. Squamish River Watershed Society
Mr. Bruce Ward. BC Ministry of the Environment
Mr. Greg Wilson. BC Ministry of the Environment

Discussion with First Nation Representative in Squamish

Although the Cheakamus is currently classified as a 'wild' stream, it is not perceived to be really wild. A dam was built in the headwaters, and dikes were built in the lower reaches to limit flooding impacts. There is also a water use plan in effect. Hatchery reared fry were released in this river during 1993-85, and more recently, the entire aquatic community was severely perturbed by the caustic soda spill. There are stories still being told about fish leaping out of the water when the contaminated water reached them. This river is no longer considered to be a truly pristine system occupied by a natural steelhead population. There is a widely shared view in the community that such human impacts must be rectified by means of further human intervention. Failure to do so has even been equated by some as a 'breach of fiduciary obligations' by the BC government. It was emphasized that important community values should be taken into account in making final decisions about hatchery supplementation. Steelhead is not an important source of food for this community, but the species is considered important for cultural and spiritual reasons, and is even referred to as ‘snake fish’. Needless to say, there is considerable support for the short-term hatchery supplementation program. In fact, during my short visit, not a single person supported the natural recovery plan.

Discussion with representative of angling guides

During a meeting with Dave Brown, I was provided copies of letters from various organizations that supported a hatchery supplementation program. The organizations included Sport Fishing Institute, the Sport Fish Advisory Board, the Pacific Salmon Forum, the South Coast Steelhead Coalition, the BC Wildlife Federation, the Squamish-Lillooet Sport Fish Advisory Committee, the Whistler Fishing Guide Association, the BC Federation of Drift Fishers, the Sport Fishing Defense Alliance, the Mayor of Whistler, the Pemberton Wildlife Association, etc. I was informed there were over 50 fishing guides operating in the vicinity of the Cheakamus River. A large amount of the business is guiding American anglers who strongly favor fishing for steelhead, as oppose to other species. Many opt for half-day guided fishing trips on the Cheakamus River, as oppose to full-day trips needed to fish on the Squamish River. Many anglers are worried that the total steelhead returns in 2008-2010 will be low, causing a severe reduction in angling opportunities, and economic hardship to those involved in guiding.

Discussion with concerned citizens from the Squamish and Whistler District

During discussion with various community members, I was told many people volunteered considerable time to assist with the assessment of the spill, the removal of carcasses, and assist with stream surveys. Many of these are upset that the MoE seemed to be doing nothing, and felt their efforts were not rewarded. Representatives of the Water Use Committee noted that even after repeated requests, efforts had never been made to remove barriers and obstacles to the upstream movement of anadromous fish near the mouth of the Cheakamus as it spills into the Squamish River.