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Review of Hatchery and Wild Salmonid Literature

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In 1977 Reginald Reisenbichler and Jack McIntyre evaluated the performance of Deschutes summer steelhead by making three crosses: hatchery x hatchery, wild x hatchery, and wild x wild and this research determined that the H x H cross performed well in the hatchery environment, the W x W cross performed better in the natural stream than in the hatchery environment, and the H x W cross was intermediate in both environments. At the time of this research, Deschutes hatchery summer steelhead were just two generations removed from the wild status. This work was done 36 years ago, but the ODFW largely ignored it and went ahead developing native broodstock hatchery programs anyway.

I am not one to jump to conclusions based on one research study, but since then there have been numerous studies that have confirmed that hatchery fish performance (reproductive fitness and survival) are inferior to that of wild fish. Those studies include chinook salmon, coho salmon, chum salmon and steelhead.

The Deschutes steelhead study by Reisenbichler and McIntyre was followed by research on the Kalama River winter and summer steelhead. This work resulted in a number of interesting papers that confirmed the Deschutes summer steelhead work, but unlike that study, the Kalama River studies involved native wild and non-native hatchery summer steelhead and the naysayers criticized that body of research on those terms. Since then work has been done that reviewed the performance of hatchery fish compared to wild fish of native stocks. The findings of those studies are summarized in the following quotes. It is due to this additional work over 36 years that I have come to accept the idea that hatchery fish have an impact on the reproductive success of native salmonids. The data supporting this conclusion is also international in scope, including steelhead and Atlantic salmon studies in Canada and Atlantic salmon studies in Europe and chum salmon in Russia.

A Few Additional Research Results:

Araki et al. 2008: "Captive breeding is used to supplement populations of many species that are declining in the wild. The suitability of and long-term species survival from such programs remain largely untested, however. We measured lifetime reproductive success of the first two generations of steelhead trout that were reared in captivity and bred in the wild after they were released. By reconstructing a three-generation pedigree with microsatellite markers, we show that genetic effects of domestication reduce subsequent reproductive capabilities by ~40% per captive-reared generation when fish are moved to natural environments. These results suggest that even a few

generations of domestication may have negative effects on natural reproduction in the wild and that the repeated use of captive-reared parents to supplement wild populations should be carefully reconsidered.”

“Our review indicates that salmonids appear to be very susceptible to fitness loss while in captivity. The degree of fitness loss appears to be mitigated to some extent by using local, wild fish for broodstock, but we found little evidence to suggest that it can be avoided altogether. The general finding of low relative fitness of hatchery fish combined with studies that have found broad scale negative associations between the presence of hatchery fish and wild population performance, should give fisheries managers pause as they consider whether to include hatchery production in their conservation toolbox.”

“Accumulating data indicate that hatchery fish have lower fitness in natural environments than wild fish. This fitness decline can occur very quickly, sometimes following only one or two generations of captive rearing.”

Araki, Hitoshi, Becky Cooper, and Michael S. Blouin. 2009. Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild. *Biological Letters* 5: (5) 621-624.

Supplementation of wild populations with captive-bred organisms is a common practice for conservation of threatened wild populations. Yet it is largely unknown whether such programmes actually help population size recovery. While a negative genetic effect of captive breeding that decreases fitness of *captive-bred* organisms has been detected, there is no direct evidence for a carry-over effect of captive breeding in their *wild-born* descendants, which would drag down the fitness of the wild population in subsequent generations. In this study, we use genetic parentage assignments to reconstruct a pedigree and estimate reproductive fitness of the wild-born descendants of captive-bred parents in a supplemented population of steelhead trout (*Oncorhynchus mykiss*). The estimated fitness varied among years, but overall relative reproductive fitness was only 37 per cent in wild-born fish from two captive-bred parents and 87 per cent in those from one captive-bred and one wild parent (relative to those from two wild parents). Our results suggest a significant carry-over effect of captive breeding, which has negative influence on the size of the wild population in the generation after supplementation. In this population, the population fitness could have been 8 per cent higher if there was no carry-over effect during the study period.

Araki and Schmid 2010: “We summarized 266 peer-reviewed papers that were published in the last 50 years, which describe empirical case studies on ecology and genetics of hatchery stocks and their effects on stock enhancement. Specifically, we asked whether hatchery stock and wild stock differed in fitness and the level of genetic variation, and whether stocking affected population abundance. Seventy studies contained comparisons between hatchery and wild stocks, out of which 23 studies showed significantly negative effects of hatchery rearing on the fitness of stocked fish, and 28 studies showed reduced genetic variation in hatchery populations. None of these studies suggested a positive genetic effect on the fitness of hatchery-reared individuals after release.

“The answer to the question whether hatchery stocking is helpful or harmful to wild stock depends on the goal of the hatcheries, species and the cases. A major limitation in our knowledge is the link between the performance of hatchery fish in the wild and their influence on the stocked populations. Parentage analyses based on genetic methods seem useful to investigate this link. Until we find a way to mitigate the negative genetic impacts on wild stock, however, hatchery stocking should not be assumed as an effective remedy for stock enhancement.”

Berejikian and Ford 2004: “All of the studies we found for Scenarios 1 (nonlocal, domesticated hatchery stocks) and 4 (captive and farmed stocks) found evidence of highly reduced relative fitness for nonlocal, domesticated hatchery stocks, captive broodstocks, and farmed populations. We therefore conclude that it is reasonable to assume that steelhead, coho, and Atlantic salmon stocks in these categories will have low (<30%) lifetime relative fitness in the wild compared to native, natural populations.”

Berntson et al. 2011. “Hatchery supplementation programs are designed to enhance natural production and maintain the fitness of the target population, however, the relative reproductive success (RRS) of hatchery-origin fish was 30–60% that of their natural-origin counterparts. There is acute interest in evaluating the reproductive performance of hatchery fish that are allowed to spawn in the wild.

Blouin 2003: “Non-local domesticated hatchery summer-run steelhead achieved 17-54% the lifetime fitness of natural native fish.”

Blouin 2009: “If anyone ever had any doubts about the genetic differences between hatchery and wild fish, the data are now pretty clear. The effect is so strong that it carries over into the first wild-born generation. Even if fish are born in the wild and survive to reproduce, those adults that had hatchery parents still produce substantially fewer surviving offspring than those with wild parents. That's pretty remarkable.”

Blouin 2009: “The implication is that hatchery salmonids – many of which do survive to reproduce in the wild– could be gradually reducing the fitness of the wild populations with which they interbreed. Those hatchery fish provide one more hurdle to overcome in the goal of sustaining wild runs, along with problems caused by dams, loss or degradation of habitat, pollution, overfishing and other causes. Aside from weakening the wild gene pool, the release of captive-bred fish also raises the risk of introducing diseases and increasing competition for limited resources.”

Blouin 2009: “There is about a 40% loss in reproductive fitness for each generation spent in a hatchery.”

Bowles 2008: “Hatchery programs are not a substitute for, or an alternative to, achieving a viable wild population according to NOAA Fisheries' Hatchery Policy. Instead, any hatchery programs have to support natural production.”

“The threats to wild populations caused by stray hatchery fish are well documented in the scientific literature. Among the impacts are substantial genetic risks that affect the fitness, productivity and genetic diversity of wild populations. Genetic risks increase substantially when the proportion of the adult population that is hatchery fish increases over 5% (Lynch and O'Hely 2001, Ford 2002).”

“Hatchery programs also pose ecological risks to wild populations that can further decrease abundance and productivity (reviewed by Kostow 2008). The level of risk is related to both the proportion of the fish in a basin that are hatchery fish and to the source of the hatchery fish. Ecological risks due to the presence of hatchery adults (including adults of a different species) have been demonstrated when the proportion that is hatchery fish is over 10% (Kostow and Zhou 2006).

“While it is reasonable to expect that a substantial decrease in hatchery fraction would contribute to recovery, the proposed hatchery actions for most of the populations are just a change in broodstock. A population that is supported by a hatchery program is not “trending toward recovery” until the hatchery influence can be removed and the wild population is demonstrated to be self-sustaining without it.”

Briggs 1953: ““It was possible to obtain some indications of the efficiency of artificial propagation through information supplied by state and federal agencies engaged in fish cultural operations in the three Pacific coast states and in New Zealand. For the portion of the life cycle up to the free-swimming fry stage, the survival of individuals was computed, beginning with the eggs which were brought upstream by the mature females. Utilizing the small amount of information available, a crude percentage survival was calculated as follows: Silver salmon, 58.5; king salmon, 65.1, and steelhead trout, 47.8 percent. These percentages may be compared to the survival data for the same three species under natural conditions in Prairie Creek: Silver salmon, 74.3; king salmon, 86.0, and steelhead trout, 64.9 percent. Therefore, there is no doubt that, during the period of study, substantially more young fish were introduced as fry into Prairie Creek via natural propagation than could be supplied through standard hatchery methods utilizing the entire run in the creek.

Buhle et al. 2009: “Our analyses highlight four critical factors influencing the productivity of these populations: (1) negative density-dependent effects of hatchery-origin spawners were ~5 times greater than those of wild spawners; (2) the productivity of wild salmon decreased as releases of hatchery juveniles increased; (3) salmon production was positively related to an index of freshwater habitat quality; and (4) ocean conditions strongly affect productivity at large spatial scales, potentially masking more localized drivers. These results suggest that hatchery programs’ unintended negative effects on wild salmon populations, and their role in salmon recovery, should be considered in the context of other ecological drivers.”

“We found that wild populations of Oregon coast coho salmon responded to changing hatchery practices during the 1990s. Productivity, expressed as the per capita growth rate in the absence of harvest, improved with reductions in the density of hatchery origin fish spawning in the wild and the numbers of hatchery smolts released into rivers. The strongest negative effects of hatcheries were associated with hatchery-reared adults breeding in the wild, precisely the pathway that might be expected to contribute most to population rebuilding.”

Chilcote et al. 1986: “The success of hatchery fish in producing smolt offspring was only 28% of that for wild fish. We also found that 62% of the naturally produced summer-run smolts were offspring of hatchery spawners. Their dominance occurred because hatchery spawners within the watershed we examined effectively outnumbered wild spawners by at least 4.5 to 1. We suggest that, under such conditions, the genetic integrity of wild populations may be threatened.”

Chilcote et al. 2010: “We found a negative relationship between the reproductive performance in natural populations of steelhead, coho, and Chinook salmon and the proportion of hatchery fish in the spawning population. We used intrinsic productivity as estimated from fitting a variety of recruitment models to abundance data for each population as our indicator of reproductive performance. The magnitude of this negative relationship is such that we predict the recruitment performance for a population comprised entirely of hatchery fish would be 0.128 of that for a population comprised entirely of wild fish. The effect of hatchery fish was the same among all three species. Further, the impact of hatchery fish from ‘wild type’ hatchery broodstocks was no less adverse than hatchery fish from traditional, domesticated broodstocks. We also found no support for the hypothesis that a population's productivity was affected by the length of exposure to hatchery fish. In most cases, measures that minimize the interactions between wild and hatchery fish will be the best long-term conservation strategy for wild populations.”

Christie et al. 2011: “These results demonstrate that a single generation in captivity can result in a substantial response to selection on traits that are beneficial in captivity but severely maladaptive in the wild. We also documented a tradeoff among the wild-born broodstock: Those with the greatest fitness in a captive environment produced offspring that performed the worst in the wild.”

Fleming and M.R. Gross 1993: “The divergence of hatchery fish in traits important for reproductive success has raised concerns. This study shows that hatchery coho salmon males are competitively inferior to wild fish, and attained only 62% of the breeding success of wild males. Hatchery females had more difficulty in spawning than wild fish and hatchery fish had only 82% of the breeding success of wild fish. These results indicate hatchery fish may pose an ecological and genetic threat to wild fish.”

Fleming et al. 1994: “Results of this study imply that hatchery fish have restricted abilities to rehabilitate wild populations, and may pose ecological and genetic threats to the conservation of wild populations.”

Ford, 2002: “Substantial phenotypic changes and fitness reductions can occur even if a large fraction of the captive broodstock is brought in from the wild every generation. This suggests that regularly bringing wild-origin broodstock into captive populations cannot be relied upon to eliminate the effects of inadvertent domestication selection.”

Ford 2010: “What is known from peer-reviewed scientific studies on the impact of hatchery salmonids on wild salmonids? Hatchery fish reproductive success is poor; there is a large scale negative correlation between the presence of hatchery fish and wild population performance; hatchery fish reproductive success is lower than for wild fish and this is true for both supplementation and production hatchery programs; there is evidence of both environmental and heritable effects; effects were detected for both release and proportion of hatchery spawners; negative correlations between hatchery influence and wild productivity are widespread; habitat or ocean conditions do not appear to explain the pattern; current science indicates that limiting natural spawning of hatchery fish is generally beneficial to wild populations; there is evidence that reducing hatchery production leads to increased wild production, and cumulative effects of hatchery could be a factor limiting recovery of some ESUs.”

Hjort and Schreck 1982: “The results of this study also suggest a potential weakness in hatchery supplementation. Selection through hatchery environment and hatchery practices may be changing the overall phenotype of hatchery stocks, as well as the between-year variability of individual genotypes (as we found for transferrin). If these changes result in reduced performance of the donor stocks in other stream systems, practices designed to increase hatchery production must be weighed against the actual benefits to wild production.”

Hulett et al. 1994: “Hatchery winter steelhead were about one-half as effective as wild winter-run steelhead in naturally producing smolt offspring. Hatchery winter steelhead were about one sixth as effective as wild winter steelhead in naturally produced adult offspring.”

ISAB 2002. “We believe that available empirical evidence demonstrates a potential for deleterious interactions, both demographic and genetic, from allowing hatchery-origin salmon to spawn in the wild. Because it is virtually impossible to ‘undo’ the genetic changes caused by allowing hatchery and wild salmon to interbreed, the ISAB advocates great care in permitting hatchery-origin adult salmon to spawn in the wild.”

ISRP 2011: “. The BACI analysis found that productivity in the Imnaha River had decreased relative to all nine unsupplemented sites. The ISRP concludes that a conservation benefit in terms of NOR abundance is unlikely from supplementation. Based on the analysis of productivity loss in the Imnaha River, the ISRP concludes that costs to population fitness are likely.

Jonsson et al. 1993: “Differences were evident for hatchery Atlantic salmon relative to wild salmon, with common genetic backgrounds, in breeding success after a single generation in the hatchery. Hatchery females averaged about 80% the breeding success of wild females. Hatchery males had significantly reduced breeding success, averaging about 65% of the success of wild males.”

Knudsen et al. 2006. “Perhaps the most important conclusion of our study is that even a hatchery program designed to minimize differences between hatchery and wild fish did not produce fish that were identical to wild fish.”

Knudsen et al. 2008: “Consequently, in this project, on a per capita basis hatchery-origin females are a minimum of 6-7% less fit than wild fish owing to lower fecundity. This demonstrates that hatcheries do not produce fish that are identical to wild fish.”

Kostow 2003 : “Our data support a conclusion that hatchery summer steelhead adults and their offspring contribute to wild steelhead population declines through competition for spawning and rearing habitats. We conclude that even though naturally spawning hatchery steelhead may experience poor reproductive success, they and their juvenile progeny may be abundant enough to occupy substantial portions of spawning and rearing habitat to the detriment of wild fish populations. Therefore, the large numbers of introduced summer steelhead would have competed heavily with wild winter steelhead for habitat resources, and this may have contributed to their decline. In the Clackamas basin, smolt offspring of hatchery fish appear to have wasted the production from natural habitat because very few to return as adults.” (emphasis added)

Kostow and Zhou 2006: “In the Clackamas River basin, the summer steelhead hatchery adults had poor reproductive success; fewer smolts were produced per parent than in the wild population, and almost no offspring of hatchery fish survived to adulthood (Kostow et al. 2003). The hatchery program was meant to provide a sport fishery, and the production of adult offspring was not intended. If successful hatchery reproduction had occurred, at least the offspring could have contributed to fisheries. Instead, the hatchery fish wasted basin capacity by occupying habitat and depressing wild production while producing nothing useful themselves. It is not unusual for hatchery adults to have poor reproductive success when they spawn naturally (other examples are provided by Reisenbichler and Rubin 1999, Kostow 2004, and McLean et al. 2004). The combined effect of poor hatchery fish fitness and depressed wild fish production due to competition with the hatchery fish poses a double jeopardy that could quickly erode natural production in any system.”

Leider, et. al., 1990: “The mean percentage of offspring from naturally spawning hatchery steelhead decreased at successive life history stages, compared to wild steelhead, from a potential of 85-87% at the egg stage to 42% at the adult stage. Reproductive success of naturally spawning hatchery steelhead compared to wild steelhead decreases from 75-78% at the subyearling stage to 10.8-12.9% at the adult stage.”

Lynch and O’Hely 2001: “Our results suggest that the apparent short-term demographic advantages of a supplementation program can be quite deceiving. Unless the selective pressures of the captive environment are closely managed to resemble those in the wild, long-term supplementation programs are expected to result in genetic transformation that can eventually lead to natural population no longer capable of sustaining themselves.”

Marchetti and Nevitt. 2003: “Our work may suggest a mechanistic basis for the observed vulnerability of hatchery fish to predation and their general low survival upon release into the wild. The brains of hatchery raised rainbow trout are smaller in 7 out of 8 critical neuroanatomical measures than those of their wild reared counterparts. Our results are the first to highlight the effects of hatchery rearing on changes in brain development in fishes.”

McClure et al. 2008: “Continued interbreeding with hatchery-origin fish of lower fitness can lower the fitness of the wild population. Generally, large, long-term hatchery programs that dominate production of a population is a high risk factor for certain viability criteria and can lead to increased risk for the population. The populations meeting ‘high viability’ criteria will necessarily be large and spatially complex. In order to meet these criteria (spatial structure and diversity) there should be little or no introgression between hatchery fish and the wild component of the population. Populations supported by hatchery supplementation for more than three generations do not in most cases meet ICTRT viability criteria at the population level.”

McLean et al. 2003: “Hatchery steelhead spawning in the wild had markedly lower reproductive success than native wild steelhead. Wild females that spawned in 1996 produced 9 times as many adult offspring per capita as did hatchery females that spawned in the wild. Wild females that spawned in 1997 produced 42 times as many adult offspring as hatchery females. The wild steelhead population more than met replacement requirements (approximately 3.7 – 6.7 adult offspring were produced per female), but the hatchery steelhead were far below replacement (<0.5 adults per female).”

Mobrand et al. 2005: “We concluded that hatcheries must operate in new modes with increased scientific oversight and that they cannot meet their goals without healthy habitats and self-sustaining naturally-spawning populations.”

Mullan. “Mean hatchery spring chinook smolt to adult survival ranged from 0.16 to 0.55%, 1976-1988 compared to wild spring chinook survival rate of from 1.6 to 8.1%. Naturally produced smolts were about 10 – 80 times as viable as hatchery smolts.”

Naylor et al. 2005: “In McGinnity and colleagues’ (2003) recent farm release study in Ireland, the lifetime success of hybrids was only 27% to 89% as high as that of their wild cousins, and 70% of the embryos in the second

generation died. These results provide strong evidence of how interbreeding might drive vulnerable salmon populations to extinction.”

Nickelson 1986: “Hatchery coho juveniles are more abundant after stocking in streams but the result is fewer adult returns and fewer juvenile coho salmon in the next generation than in streams that were not stocked.”

Nickelson 2003: “Hatchery programs designed for harvest augmentation should be removed from basins with habitat that has high potential to produce wild salmonids. To aid recovery of depressed wild salmon, the operation of hatcheries must be changed to reduce interactions of hatchery smolts with wild smolts. A program that reduces harvest, restores habitat, and reduces hatchery effects is necessary.”

NMFS 2010: “Hatchery production has been reduced to a small fraction of the natural-origin production. Nickelson (2003) found that reduced hatchery production led directly to higher survival of naturally produced fish, and Buhle et al. (2009) found that the reduction in hatchery releases of Oregon coast coho salmon in the mid 1990's resulted in increased natural coho salmon abundance.”

ODFW 2010: “Chilcote and Goodson examined data sets on population abundance for 121 populations of coho, steelhead, and Chinook in Oregon, Washington, and Idaho. They found that population productivity was inversely related to the average proportion of hatchery fish in the naturally-spawning population, consistent with the findings of Buhle et al. (2009). The magnitude of this effect was substantial. For example, a population comprised entirely of hatchery fish would have one tenth the intrinsic productivity of one comprised entirely of wild fish. There was no indication that the significance or strength of this relationship was different among the three species examined (chinook, coho and steelhead). In addition, there was no indication that the type of broodstock (integrated with the local natural-origin population versus segregated) affected the significance or intensity of the response.” (Section 2: Updating the Scientific Information in the 2008 FCRPS BiOp May 20, 2010, Page 118 and Lower Columbia River Salmon Recovery Plan 9-2010 ODFW)

ODFW 2010a: “For example, the reduction in productivity between a population comprised entirely of wild fish and one comprised of equal numbers of hatchery and wild fish is 66 percent for steelhead, 76 percent for coho, and 43 percent for Chinook.”

Paquet et al. 2011: ““Hatcheries are by their very nature a compromise – a balancing of benefits and risks to the target populations, other populations, and the natural and human environment they affect.”

Reisenbichler 1986: “Most (hatchery fish) outplanting programs have been unsuccessful. Rigorous planning, evaluation, and investigation are required to increase the likelihood of success and the ability to promptly discern failure.”

Reisenbichler 1992: “Because anadromous salmonids home to their natal streams to spawn, managers can expect the fish in different streams to be from genetically distinct stocks. We recommend that steelhead from different coastal drainages be considered and managed as distinct stocks.”

Reisenbichler 1994: “Gene flow from hatchery fish also is deleterious because hatchery populations genetically adapt to the unnatural conditions of the hatchery environment at the expense of adaptedness for living in natural streams. This domestication is significant even in the first generation of hatchery rearing.”

Reisenbichler 1996: “Available data suggest progressively declining fitness for natural rearing with increasing generations in the hatchery. The reduction in survival from egg to adult may be about 25% after one generation in the hatchery and 85% after six generations. Reduction in survival from yearling to adult may be about 15% after one generation in the hatchery and 67% after many generations.”

Reisenbichler and Rubin 1999: “Although several studies have shown genetic differences between hatchery and wild anadromous Pacific salmon (*Oncorhynchus* spp.), none has provided compelling evidence that artificial propagation poses a genetic threat to conservation of naturally spawning populations. When the published studies and three studies in progress are considered collectively, however, they provide strong evidence that the fitness for natural spawning and rearing can be rapidly and substantially reduced by artificial propagation. This issue takes on great importance in the Pacific Northwest where supplementation of wild salmon populations with hatchery fish has been identified as an important tool for restoring these populations. Recognition of negative aspects may lead to restricted use of supplementation, and better conservation, better evaluation, and greater benefits when supplementation is used.

“Apparently domestic selection is often intense. The fitness of stream type chinook (spring chinook) salmon was diminished after four generations of culture, despite continuous gene flow from the wild population (on average, wild fish comprised 38% of the hatchery broodstock). The fitness of steelhead was diminished after only two generations in the hatchery (Reisenbichler and McIntyre, 1977). Presumably substantial change occurs in the first generation.”

“These conclusions imply that supplementation (wherein wild fish interbreed with hatchery fish of reduced fitness) will reduce the productivity of naturally spawning populations, and often may compromise conservation objectives.”

Schroder, et al. 2008: “Pedigree assignments based on microsatellite DNA, however, showed that the eggs deposited by wild females survived to the fry stage at a 5.6% higher rate than those spawned by hatchery females. Subtle differences between hatchery and wild females in redd abandonment, egg burial, and redd location choice may have been responsible for the difference observed. Other studies that have examined the effects of a single generation of hatchery culture on upper Yakima River chinook salmon have disclosed similar low-level effects on adult and juvenile traits. The cumulative effect of such differences will need to be considered when hatcheries are used to restore depressed populations of chinook salmon.”

Seamons et al. 2012. “We tested the efficacy of the strategy of segregation by divergent life history in a steelhead trout, *Oncorhynchus mykiss*, system, where hatchery fish were selected to spawn months earlier than the indigenous wild population. The proportion of wild ancestry smolts and adults declined by 10–20% over the three generations since the hatchery program began. Up to 80% of the naturally produced steelhead in any given year were hatchery/wild hybrids.

“...proportions of hybrid smolts and adults were higher in years when the number of naturally spawning hatchery-produced adults was higher. Divergent life history failed to prevent interbreeding when physical isolation was ineffective, an inadequacy that is likely to prevail...”

“Controlling the behavior or breeding biology of captively reared animals released into the wild is one of the most significant issues for managers tasked with minimizing risks associated with captive rearing.

Steward et al. 1990: Authors reviewed 606 hatchery supplementation studies and found that few directly assessed the effects on natural stocks. Genetic and ecological effects and changes in productivity of the native stocks that can result remain largely unmeasured. However, the general failure of supplementation to achieve management objectives is evident from the continued decline of wild stocks.

Vincent 1987: Hatchery stocking ended in a Montana stream and wild trout more than doubled (160%) and the wild trout biomass increased by 10 times.

Theriault et al. 2011: “Supplementation of wild salmonids with captive-bred fish is a common practice for both commercial and conservation purposes. However, evidence for lower fitness of captive reared fish relative to wild fish has accumulated in recent years, diminishing the apparent effectiveness of supplementation as a management tool. To date, the mechanism(s) responsible for these fitness declines remain unknown. In this study, we showed with molecular parentage

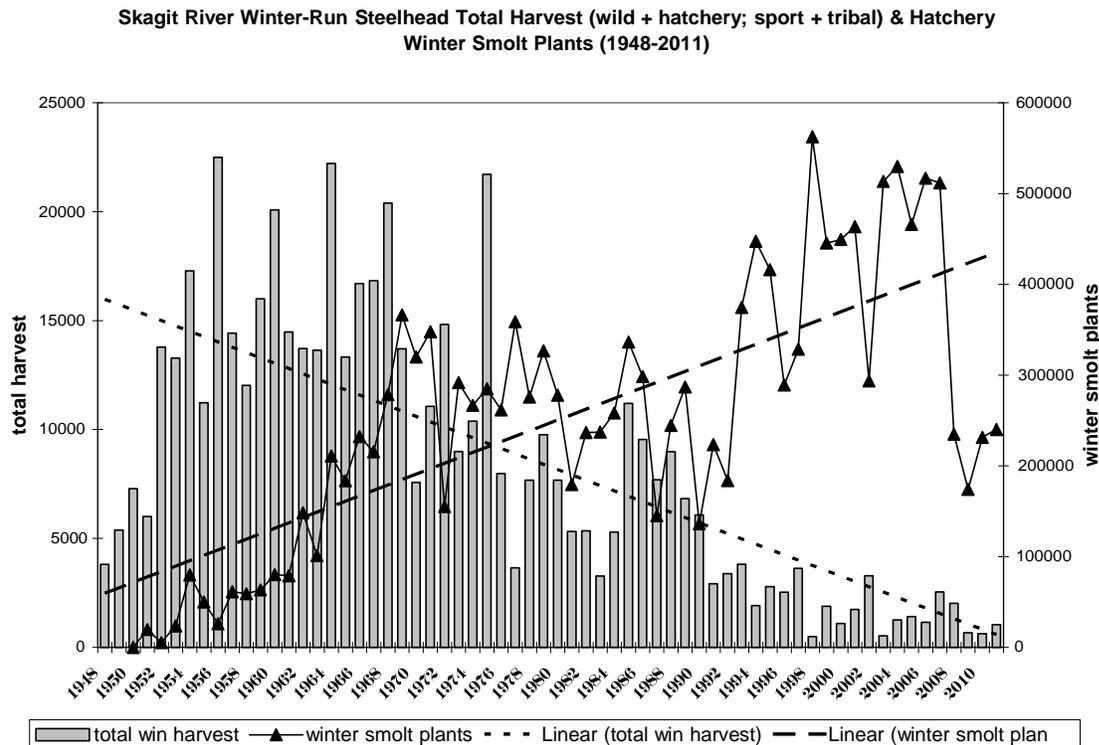
analysis that hatchery coho salmon (*Oncorhynchus kisutch*) had lower reproductive success than wild fish once they reproduced in the wild. This effect was more pronounced in males than in same-aged females. Hatchery spawned fish that were released as unfed fry (age 0), as well as hatchery fish raised for one year in the hatchery (released as smolts, age 1), both experienced lower lifetime reproductive success (RS) than wild fish.

Wohlfarth 1986: Stocking with hatchery stocks cannot replace wild productivity because hatchery fish are selected for adaptation to the hatchery environment and do not perform well in the natural environment.

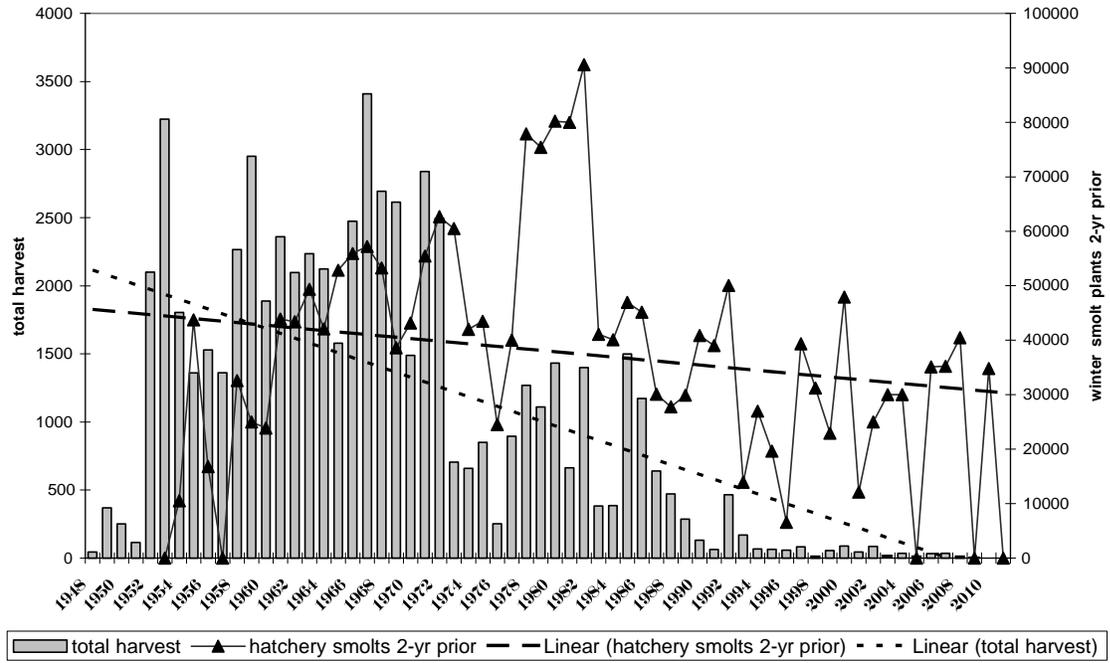
Wood, et al., 1960: Hatchery coho salmon 14 months after release into a stream did not reach the body composition of the wild salmon in time for downstream migration and had lower ocean survival.

Zaporozhets: 2011. We document evidence of life history trait divergence between wild and hatchery salmon in Kamchatka region of the Russian Federation. Specifically, we document cases where hatchery salmon return at younger ages and smaller sizes and exhibit lower life history diversity compared to their wild counterparts. We feel a broader, ecosystem level approach to managing salmon hatcheries is warranted, as proposed by Lichatowich (1999) and Williams et al. (2003), to help ensure that hatchery fish are raised in conditions that more closely match those in the natural environment and hatchery risks are contained by adopting precautionary management approaches to help conserve wild salmon populations. We stress the importance of preservation of wild salmon populations, and we encourage further studies to more fully understand the consequences of interactions between wild and hatchery salmon.

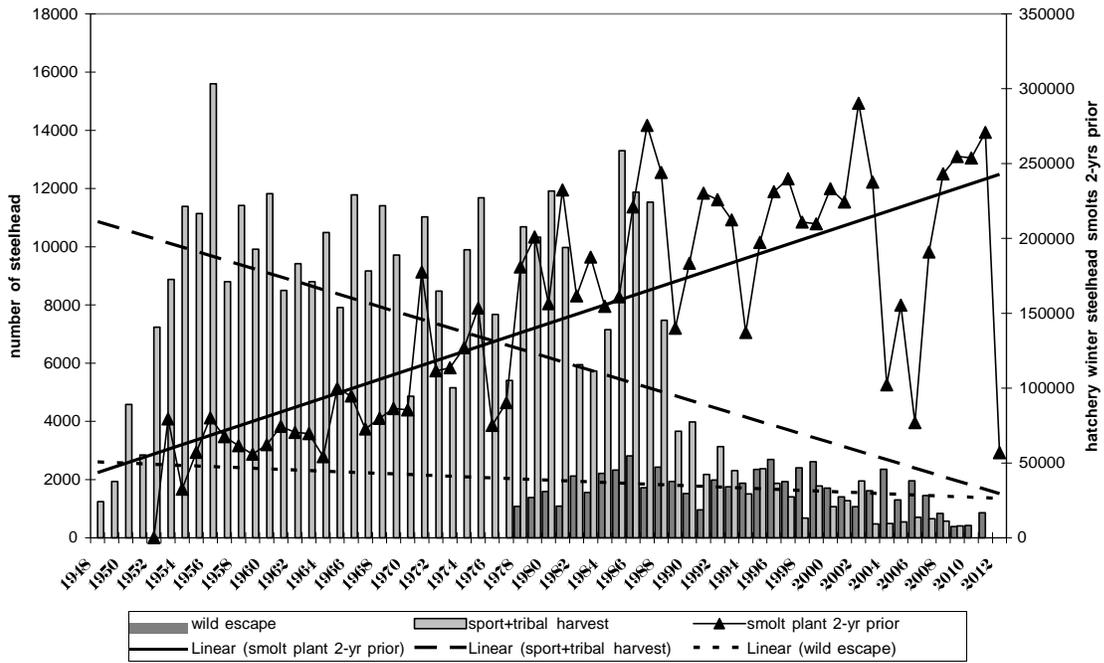
Impact of Hatchery Releases on Sport Harvest:



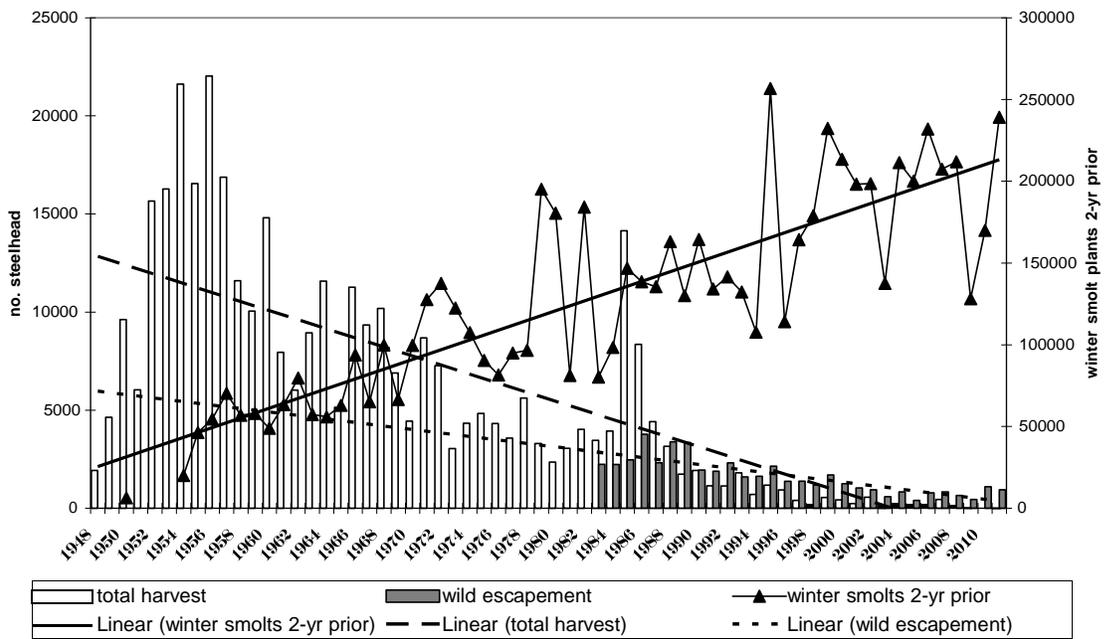
Samish River Winter-Run Steelhead Total Harvest (wild + hatchery; sport + tribal) & Hatchery Winter Smolt Plants 2-Years Prior to Align with 2-Salt Returns (1948-2011)



Green River Winter Steelhead Wild Escapement (1978-2011) & Total Harvest (1948-2009) & Hatchery Winter Steelhead Smolt Plants 2-Years Prior to Align with 2-Salt Returns (1951-2011)

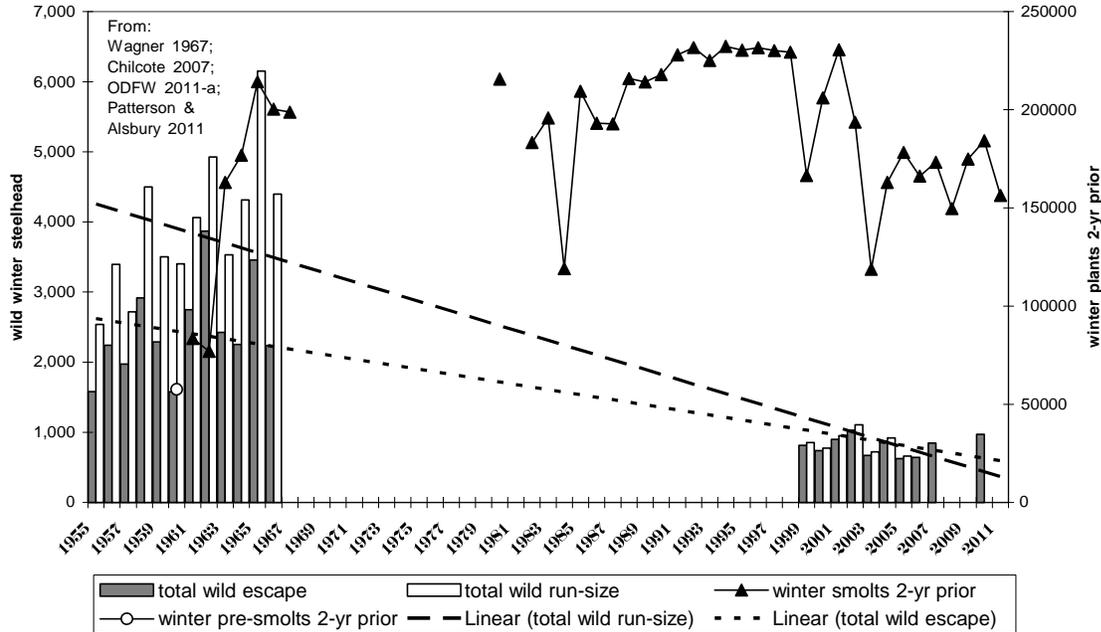


Puyallup River Winter-Run Steelhead Total Harvest (wild + hatchery; sport + tribal, 1948-2011), Wild Escapements (1983-2011) & Hatchery Winter Smolt Plants (1953-2011) 2-Years Prior to Align with 2-Salt Returns

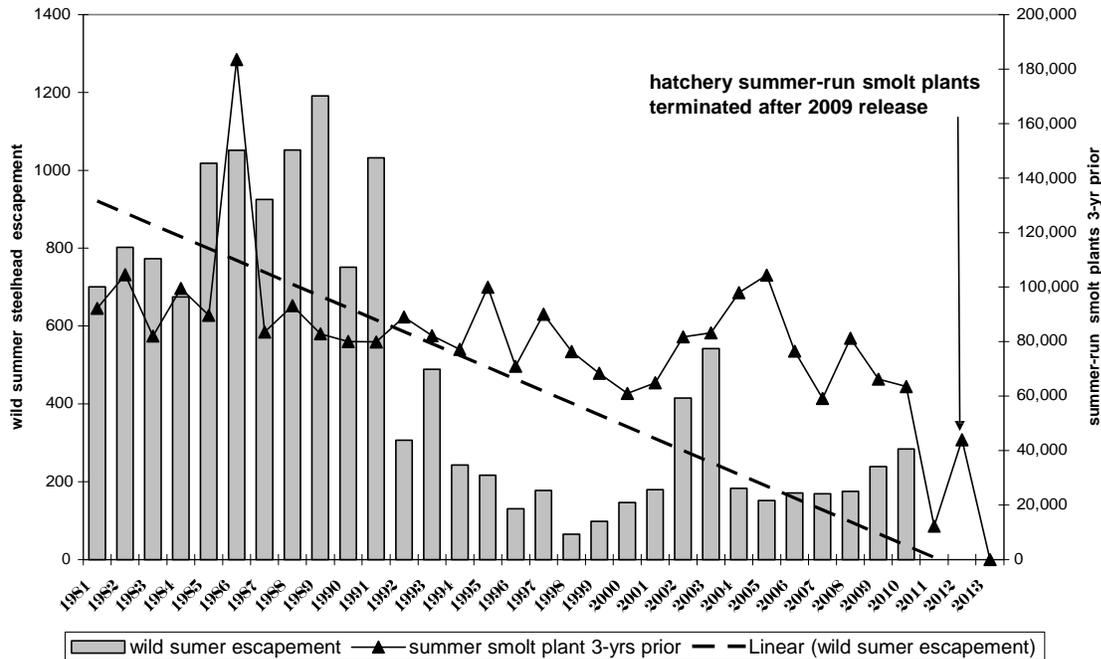


Impact of Hatchery Releases on Wild Steelhead:

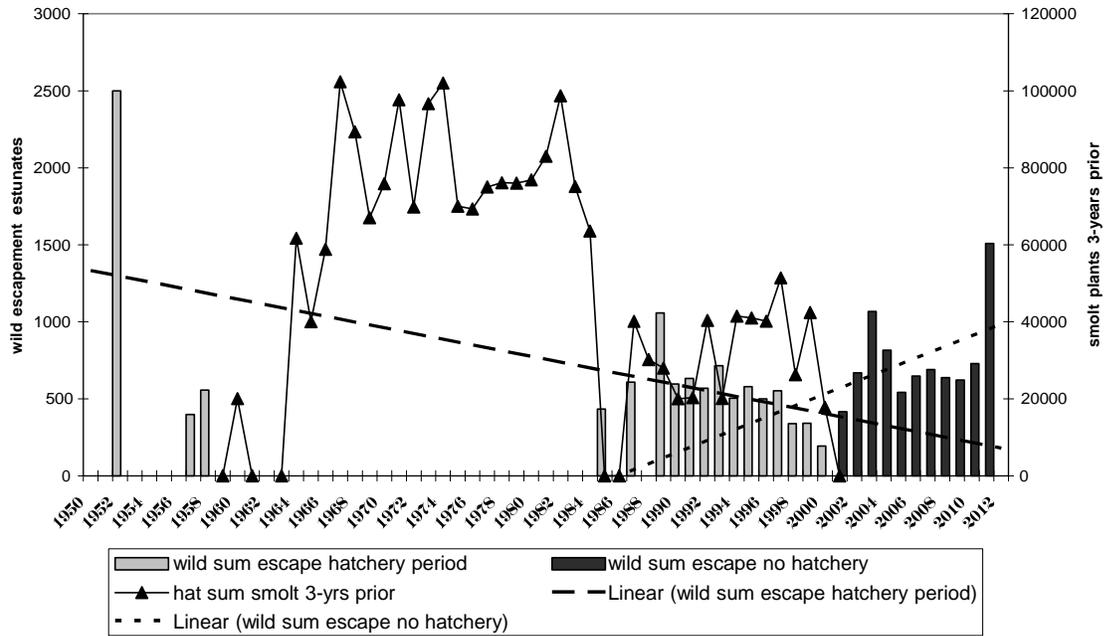
Sandy River Wild Winter-Run Steelhead Escapements & Run-Sizes Over 2 Different Periods & Hatchery Winter Smolt & Pre-Smolt Plants 2-Years Prior to Align with 2-Salt Spawn Year Returns (1955-2011)



Hood River Wild Summer-Run Steelhead Escapements & Hatchery Summer Steelhead Smolt Plants 3-Years Prior to Align with 2-Salt Spawn Year Returns (1981-2013)



Wind River Wild Summer-Run Steelhead Escapement Estimates for Years Available & Hatchery Summer Smolt Plants 3-Years Prior to Align with 2-Salt Spawn Year Returns (1950-2011)



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