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Effects of hatcheries and environmental variation on threatened populations of wild salmon

An important study on the effects of hatchery coho salmon on wild coho in Oregon coastal rivers has been published by Elsevier. This study includes environmental influence on productivity, noting the combined effects of ocean, freshwater and hatchery fish on the productivity of wild coho, an ESA-listed species.

The following are excerpts from this study:

"Conservation of Pacific salmon (Oncorhynchus spp.) has been particularly plagued by ecological complexity and multiple causation. Salmon populations have declined dramatically since the 1800s due to overharvest, dam construction, and land use practices such as logging, mining, and agriculture (Ruckelshaus et al., 2002). Salmon are also highly sensitive to large-scale climatic fluctuations, particularly during the oceanic phase of their life cycle (Hare et al., 1999). As a result of this suite of impacts, 28 Evolutionarily Significant Units (ESUs) of Pacific salmon and steelhead in Washington,Oregon, and California are now listed under the U.S. Endangered Species Act (Ruckelshaus et al., 2002). Although the causes of salmon declines are well-documented, quantifying their individual contributions in specific cases has been difficult, leading to uncertainty and controversy (Lichatowich, 1999; Hoekstra et al., 2007).

"Since the early 20th century, hatchery programs have often been viewed as a solution to declining salmon abundance and fishery yields (Lichatowich, 1999; Naish et al., 2008). However, evidence increasingly suggests that traditional hatchery programs aimed at producing fish for harvest may actually contribute to the decline of wild populations.

"Many hatchery programs have begun to scale back releases in light of these potential risks. On the Oregon coast, releases of juvenile coho salmon (Oncorhynchus kisutch) dropped from a historic high of 34 million in 1981 to an average of 1.6 million from 1998 to 2002 in an effort to protect wild populations (Nicholas et al., 2005). The Oregon Coast coho ESU is listed as Threatened under the Endangered Species Act, and populations are currently at 3–19% of their historical abundance (Meengs and Lackey, 2005).

“Previous studies (Emlen et al., 1990; Nickelson, 2003) have found evidence that hatchery releases negatively affect productivity of Oregon coast coho, but have not quantified the magnitude of this effect relative to other ecological factors.

“Our study included 15 ‘‘independent” populations (i.e., those whose persistence does not depend on immigration from other basins; Chilcote et al., 2005) of coho salmon within the Oregon Coast ESU.

“State-operated hatcheries throughout the region rear juvenile coho and release them into surrounding watersheds. Upon returning as adults, some of these hatchery-origin fish spawn in the wild. Our analysis examined potential impacts on wild populations resulting from hatchery juveniles released into each river basin and hatchery-origin adults on the natural spawning grounds. … To represent the influence of freshwater habitat conditions on productivity, we included estimates of smolt carrying capacity for each basin based on the available area of high-quality juvenile overwintering habitat (Nickelson, 1998; Nicholas et al., 2005).

“To account for the influence of ocean conditions, we obtained time series of four oceanographic variables previously shown to explain 75% of the variation in smolt-to-adult survival of coho salmon off the Oregon coast (Logerwell et al., 2003): mean January–March sea surface temperature (SST) in the year of seaward migration and the winter spent at sea, April–June sea level during the first spring at sea, and date of the spring transition from downwelling to upwelling during the first year at sea (see Logerwell et al., 2003 for details). Initial model comparisons indicated that the two SST variables had the largest effects on productivity…

“Productivity of Oregon coast coho salmon declined gradually from brood year 1990 to 1993, dropped abruptly from 1994 to 1996, and then recovered and remained relatively stable from 1997 to 2000. Productivity was generally low when sea surface temperature was high, and the recovery coincided with a shift to cooler conditions. Hatchery operations also changed dramatically during the 1990s; smolt releases were sharply curtailed beginning in 1996 and densities of hatchery spawners in streams began to decline as well, although the abundance of hatchery smolts and adults was highly variable across river basins. The highest hatchery spawner densities occurred in 1994–1996, when productivity was lowest.

“We found that on a per capita basis, hatchery-origin spawners had much stronger density-dependent effects on productivity than did wild-origin spawners.

“Our analyses also indicated that productivity declined as increasing numbers of hatchery smolts were released into a river basin.

“…hatchery fish spawning in the wild did in fact produce surviving recruits in sufficient numbers to influence patterns of overall productivity.

“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. Density-dependence driven by spawner abundance had an overriding influence, but hatchery-origin spawners had much stronger negative per capita effects than wild-origin spawners. One implication is that a population of adults containing a large fraction of hatchery fish will produce fewer recruits than an all-wild population at any given density.

“…a pure hatchery-origin population would produce 45% as many recruits as a pure wild-origin population. This predicted discrepancy remains substantial even at the critically low densities where extinction risk is greatest

“Another consequence of asymmetric density-dependence is that the presence of hatchery-origin spawners will reduce the carrying capacity of a wild population (see also Kostow and Zhou, 2006). Our results are consistent with those of Chilcote (2003), who found a negative relationship between intrinsic growth rates of steelhead trout (O. mykiss) populations and the average proportion of hatchery spawners in each river.

“Hatchery smolt releases also impacted wild coho productivity, although not as strongly as hatchery-origin adults. Since most hatchery coho smolts migrate downstream soon after release, interactions with wild fish might be expected to occur primarily in the estuary and near-shore environment.

“These results suggest that although large-scale climatic forcing likely accounted for the majority of the increase in coho population growth rates, reformed hatchery operations played an important role as well. Notably, the only scenario in which productivity remained below zero (i.e., populations continued to decline on average) after the 1996 brood year was the case with both high hatchery output and poor ocean conditions.

“…if hatchery-origin fish have lower fitness (i.e., intrinsic productivity) than wild fish in the natural environment, then the average productivity of a mixed population would decrease as the proportion of hatchery fish increases. There is evidence that adult coho (Fleming and Gross, 1993) and other salmonids (e.g., Araki et al., 2007) reared in hatcheries experience reduced reproductive fitness due to genetic and environmental effects on size at maturation, run timing, behavior, and other traits (reviewed in Berejikian and Ford, 2004). In addition, the relative reproductive success of hatchery adults may decline with increasing spawner density (Fleming and Gross, 1993), which could magnify the differences in per capita effects.

“…if these fitness differences have a genetic basis, introgression could eventually reduce the fitness of the wild population (Ford, 2002) as seen in some European salmonids (Naish et al., 2008). Genetic effects likely do not explain the changes in productivity in response to year-to-year fluctuations in hatchery spawners that we observed, but it is possible that decades of hatchery production have eroded the fitness of wild Oregon coast coho, as hatchery adults have been observed on the spawning grounds in every population in this study. The true relative fitness of hatchery fish likely lies between these extreme values of 0 and 1.

“hatchery-reared juvenile salmonids often hatch earlier, grow faster, and display more agonistic behavior than wild juveniles, and these differences may be heritable…

“hatchery-reared juvenile Oregon coast coho displaced their smaller wild conspecifics, but subsequently had poor survival and contributed little to adult returns. Hatchery-reared juvenile salmonids may also attract predators (Beamish et al.,1992)…

“In our study, 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. It is possible that supplementation hatcheries, which are designed to integrate wild and captive-reared animals to provide a buffer for populations approaching critically low abundance, might minimize these detrimental impacts (Naish et al., 2008). However, even conservation oriented hatchery programs may face a trade-off between modest increases in abundance and depressed productivity of wild fish (Oosterhout et al., 2005). Our results show that this trade-off is likely to depend on the environmental context of hatchery operations. For example, releasing large numbers of captive-reared juveniles could pose a greater risk to wild populations during periods of poor ocean survival; however, these same conditions might be seen as a reason to initiate supplementation (Oosterhout et al., 2005). In cases like this, a more effective recovery strategy might focus on minimizing direct threats to survival (e.g., overharvest) and restoring habitats to provide populations with resilience under varying climatic conditions."

Source:

Buhle, Eric, R., Kristin K. Holsman, Mark D. Scheuerell, Andrew Albaugh. 2009. Using an unplanned experiment to evaluate the effects of hatcheries and environmental variation on threatened populations of wild salmon. Biological Conservation. Elsevier Ltd. www.elsevier.com or

http://www.nativefishsociety.org/conservation/biblio/wild_vs_hatchery/documents/Buhle_et_al_2009Biol_Conserv.pdf

Hatchery Fish Management Zones And Extinction of Wild Fish

Sam Wright is a retired biologist that worked for the Washington Department of Fish and Wildlife. His career is noted for progressive conservation management of trout, steelhead, and salmon. After retirement he did not pack his tent for Baja and remained engaged in key fish management issues. His petition to protect Puget Sound steelhead under the ESA resulted in their protection as a threatened species. The following letter to the WDFW Commission reveals an insiders understanding of an issue he worked to resolve when he worked for the agency. He takes us deep for a rare look into the machinery of government management of salmonids that only an insider can accomplish.

WILD FISH EXTINCTIONS CAUSED BY THE LONG-TERM USE OF HATCHERY FISH ZONES TO MANAGE PACIFIC SALMON (*ONCORHYNCHUS*) IN WASHINGTON AND OREGON

A common management practice in Washington and Oregon since the early 1960s is the planned, deliberate overfishing and eventual extinction of wild Pacific salmon populations in order to harvest comingled populations of salmon that are produced by artificial production (Wright 1993). In Washington, the Final Environmental Impact Statement (EIS) for the Wild Salmonid Policy identified 89 separate naturally spawning Pacific salmon populations that were being subjected to this practice or nearly one-third of all existing Pacific salmon populations in the State (Washington Department of Fish and Wildlife (WDFW) 1997: Table II-1, p. 9).

I was the project leader and lead author for this EIS process and had to work with an Assistant Attorney General (AG) assigned to WDFW. My original language in Table 3 described the process in part as "planned, deliberate overfishing and eventual extinction of wild salmon populations in order to harvest comingled hatchery fish". The AG stated that "this sounded like something illegal" and changed the language of the Table title to "Current fish management plans and practices overfish 89 wild stocks in order to harvest comingled hatchery fish at rates that are not sustainable by wild populations." This is an example of one of many ways that have been used to disguise the process.

My initial attempt to stop this practice occurred in the early 1980s when I was administrator of the Habitat Management Division for the Washington Department of Fisheries (WDF). My work included involvement in a wide array of habitat protection, enhancement and mitigation projects. I soon began to wonder if I was knowingly committing illegal acts. Was it illegal to commit public funds to habitat improvement work when I knew that viable adult salmon spawners were never going to be provided to reap projected project benefits? Was it illegal to force a landowner to correct an upstream fish passage problem when I knew that spawners were never going to be provided to utilize habitat above the obstruction? Was it illegal to force a developer to fund a costly mitigation project when I knew that spawners were never going to be provided to justify the expenditure? I was also concerned that the "secret" would eventually be revealed to the public and that this could destroy our future ability to protect salmon habitat.

In 1982, I advised WDF that it was essential to end this practice since it was probably illegal in several different respects. The practice appeared to be illegal under the legislation that created WDF and had never been reviewed under the State Environmental Policy Act (SEPA). In addition, all of the more recent hatcheries requiring environmental reviews did not even hint at this practice in their environmental documents. At best, the practice was simply very poor resource stewardship. I then provided a plan to eliminate this practice that was later described in Wright (1993).

The first part of my recommendation was to mark all hatchery Chinook salmon (*O. tshawytscha*) and all hatchery coho salmon (*O. kisutch*) by removal of their adipose fins. The basic principle involved was the ability to manage wild and hatchery salmon as "separate species" and the adipose mark enabled this to be done in practice. The second part of my recommendation was that natural spawning escapement objectives needed to be established for all existing naturally spawning salmon populations and that all fisheries would then be managed to achieve these objectives. The third part of my proposal was that existing and planned hatchery programs would be adjusted as necessary to make them compatible with achieving these natural spawning escapement objectives.

The adipose marking proposal was initially rejected by everyone, but gradually came to be accepted and is now widely implemented. The problem is that it was decoupled from both the establishment and management for natural spawning escapement objectives and the need to make hatchery programs compatible. Adipose marking is meaningless by itself when the same high exploitation rates continue to be applied in non-selective fisheries harvesting comingled wild plus hatchery salmon and hatchery programs continue to be incompatible.

My only successful attempt to expose this problem in a formal publication occurred in Wright (1993). The subtitle was "Salmon managers need to abandon the use of hatchery fish management zones." WDF tried to stop publication but had to settle for a disclaimer stating that "The views in this essay are those of the author and do not necessarily represent those of the Washington Department of Fisheries." There was a great deal of luck involved in the peer review process since two of three reviewers were not from Washington or Oregon. Two subsequent attempts to expose the problem in formal publications failed when the majority of peer reviewers were from Washington and Oregon.

I initially had high hopes for resolution of the problem when Puget Sound Chinook and Lower Columbia River Chinook were listed as Threatened under the Endangered Species Act. Both areas had many Chinook populations on the list of 89 that were being deliberately overfished (WDFW 1997). However, all of these same populations were then assumed to be indistinguishable from hatchery Chinook or "genetically extinct" as wild populations. In Puget Sound, a total of 37 defined Chinook salmon populations were divided into 22 "A" and 15 "B" populations, with the latter group judged to be extinct. The situation in the Lower Columbia River was far worse, with North Lewis River fall Chinook being the only remaining population that was not determined to be extinct.

Unfortunately, my prediction of mass extinctions had been fulfilled. This extinct classification allowed the status quo practices of existing hatchery programs and high exploitation rates to continue for all of these populations. Some even had "escapement goals" identified to complete the public illusion of responsible resource management. Many hatchery Chinook never make it all the way back to existing hatchery traps and end–up spawning naturally. These can then be identified as an escapement goal without compromising the desired hatchery programs and high exploitation rates.

Over the years, there have been many varied attempts to disguise hatchery fish zones such as the "escapement goals" established for 15 Puget Sound "B" group Chinook salmon populations. The only citable reference that precisely identifies salmon populations where there is clear, unambiguous management intent to put adequate numbers of viable natural spawners on the spawning grounds is the Salmon Fishery Management Plan of the Pacific Fishery Management Council (PMFC 2003: Table 3-1,15p.). This confirms the solitary status of North Lewis River fall Chinook and that both the entire Columbia River system and the entire South Puget Sound Region are huge hatchery fish zones for coho salmon. As predicted for wild Chinook salmon, there have also been massive extinctions of wild coho salmon populations.

The common practice of deliberately overfishing naturally spawning salmon populations in order to harvest comingled hatchery fish continues to be alive and well in Washington and Oregon (albeit with some new disguises commonly called "hatchery reform"). The solution is still exactly what it was in 1982. At a minimum, resource managers in Washington and Oregon should at least be honest about what they are doing so that countless millions of dollars will not continue to be spent in hatchery fish zones when the same money could be spent much more productively in wild salmon zones. Hundreds of millions of dollars have already been spent and the management status (wild or hatchery zones) has never been used (as a criteria) to prioritize competing project proposals.

References

PFMC 2003. Fishery management plan for commercial and recreational salmon fishery off the coasts of Washington, Oregon and California as revised through Amendment 14. Pacific Fishery Management Council, Portland, OR.

WDFW 1997. Final environmental impact statement for the Wild Salmonid Policy. Washington Department of Fish and Wildlife, Olympia, WA.

Wright, S. 1993. Fishery management of wild Pacific salmon stocks to prevent extinctions. Fisheries 18(5):3-4.

QUOTES FROM THE GUIDANCE FOR MONITORING RECOVERY OF PACIFIC

NORTHWEST SALMON AND STEELHEAD

HARVEST THREATS TO WILD SALMONIDS:

The following quotes are taken from a 2009 guidance letter from the National Marine Fisheries Service to the state and tribal fish managers for monitoring recovery of ESA-listed salmonids. This guidance document would vastly improve management for wild, native salmonids and provide the basis for recovery of ESA protected fish. This guidance is scientifically sound and should be carried out by those managing harvest and hatchery programs. There is nothing in this guidance that the fish managers do not already know and have known for many decades, so the issue is compliance. Will the fish managers comply with this guidance? If they do not, then will NMFS do more than make suggestions?

"Harvest of listed species, though incidental can have a major impact on small populations.

"It is important that the management agencies and tribes directing harvest regimes can demonstrate that harvest is not a threat to recovery.

"In the past hatchery fish have been used to determine harvest percentages in coastal fisheries because they are easily accessed and marked with a CWT (coded wire tag). It has been assumed that nearby natural stocks will migrate in a similar manner to hatchery fish and also encounter fisheries in a similar manner. These assumptions may not hold true for many populations.

"These tag recoveries have been used in run reconstruction scenarios to estimate the percent harvest and harvest exploitation rate in each of the identified coastal and inland fisheries. Although this system provided huge improvements in stock management, the "stocks" managed have been by necessity aggregates of hatchery and wild populations based upon assumed common migration routes and common geographic origins. Hatchery CWT recoveries have been used as the surrogate for estimating interceptions of wild populations as part of stock aggregates but not successful in delineating individual populations within the stock aggregate.

"It is recognized that stock aggregates no longer provide the management resolution necessary for estimating harvest impact to recovering populations listed under the ESA. (emphasis added) Therefore, either a shift must be made from stock aggregate management to population management, or existing fisheries will no longer be able to function due to the inability to quantify their jeopardy impact on listed populations and ESUs.

"Harvest curtailment to address ESA listed species has been used as a strategy to increase spawner escapements and therefore viability of listed populations. However, monitoring is needed to demonstrate that these strategies have been effective in meeting the desired reduction in interception of ESA populations.

"Because harvest removes potential spawners from the population and thus reduces the potential number of eggs that could be deposited and the potential number of emergent fry available to fill the habitat, it is important to understand what impact exploitation rate regimes are having on the rate of recovery in terms of time and spatial distribution.

"If it can be shown that the number of available spawners is fully capable of seeding all available habitats, then recovery rates will depend upon improvements in habitat or some other threat. If it cannot be demonstrated that sufficient spawners are available to fully seed the habitat, then any allowable exploitation rate will potentially prolong the recovery process. Those impacts should be modeled and available for all recovery participants to evaluate.

"Monitoring of natural origin adults should demonstrate that harvest exploitation rates on natural origin listed populations were minimal and that the escapements necessary for building populations back to target viability levels were achieved.

"In conjunction with selective harvest strategies targeting hatchery fish, the states and tribes should continue their evaluation of selective fishing gear and methods to demonstrate reductions in impacts to natural origin spawners.

"The effectiveness of harvest curtailment strategies is validated when the adult to adult productivity ratios are calculated and the percent of total natural production that is harvested is determined to be at the level that does not interfere with meeting or achieving viability productivity goals.

"Although spawner abundance is the defining information needed to determine viability, one of the metrics of interest to those working toward recovery is the total number of adults returning from the sea and how did harvest affect the number available for spawning and recovery. This metric is crucial in validating that the management actions taken by federal, state, and tribal harvest managers have been sufficient."

<u>HATCHERY THREATS TO WILD SALMONIDS:</u>

"Although it is challenging to quantify the impact of changes in specific diversity traits, such as run timing or age at maturity, on eventual population and species persistence, one likely outcome of adverse changes in diversity is loss of reproductive success.

"…hatchery reared fish are believed to genetically diverge from wild fish as they adapt to survive in the novel hatchery environment. A number of studies (e.g. (Leider, 1990); (Kostow 2003); (Berejikian 2004; (Araki 2008) have reported that when such hatchery fish return and spawn under natural stream conditions among themselves or with a wild fish, their ability to produce viable offspring is much reduced relative to paired wild fish in the same environment. The magnitude of this difference has generally been found to be quite large and may be related to population productivity. For example, Chilcote (2003) found that a spawning population of equal numbers of hatchery and wild steelhead would produce up to 63% fewer recruits per spawner than one comprised entirely of wild fish. **If these findings can be applied broadly, then there could be situations where wild production of smolts could be increased by up to three times by restoring genetic diversity to the natural wild populations where such diversity has been lost and by excluding hatchery fish from spawning areas so that additional erosion of genetic fitness cannot occur.** (Emphasis added)

"…a successful (integrated hatchery) program would have few hatchery fish straying into the spawning grounds and many natural fish available for cross spawning in the hatchery.

(*Note: This suggests that integrated hatchery programs are dependent upon having access to viable, healthy and abundant wild salmonids in order to function properly While the HSRG prescription is to allow a fraction of the natural spawners to be hatchery fish, this statement takes a more cautious approach. Based on the best available science, there is no justification to manage for an integrated hatchery program recommended by the HSRG)*

"…growing evidence has indicated that hatcheries can have substantial adverse impacts upon wild populations due to competition, genetic introgression, harvest exploitation rates and disease.

"McElhany (2000) concluded that valid estimates of natural productivity are impossible to obtain for supplemented populations in which the abundance of naturally produced and hatchery produced fish on the spawning grounds are not estimated separately.

"…we are recommending that all hatchery fish not marked externally be coded wire tagged so that they are detectable with CWT wands in the fisheries, at counting facilities, and on the spawning grounds.

"Programs need to monitor the genetic characteristics of brood stock to prevent the homogenization of the stock or alteration of gene flow over time. **Baseline genetic monitoring is essential** and should support current GSI (genetic stock identification) work with salmonids across the Pacific Northwest." (Emphasis added)

(Note: In the1994 Fish and Wildlife Program adopted by the Power Planning and Conservation Council, I was successful in securing a genetics baseline study for the Columbia River Basin, however, this was never funded.)

Source:

http://www.nwr.noaa.gov/Salmon-Recovery-Planning/upload/Draft-RME-Guidance.pdf

Crawford, Bruce A. and Scott Rumsey. June 12, 2009. Guidance for monitoring recovery of Pacific Northwest salmon and steelhead listed under the federal Endangered Species Act (Idaho, Oregon, and Washington) National Marine Fisheries Service. Northwest Region. Pp 129.