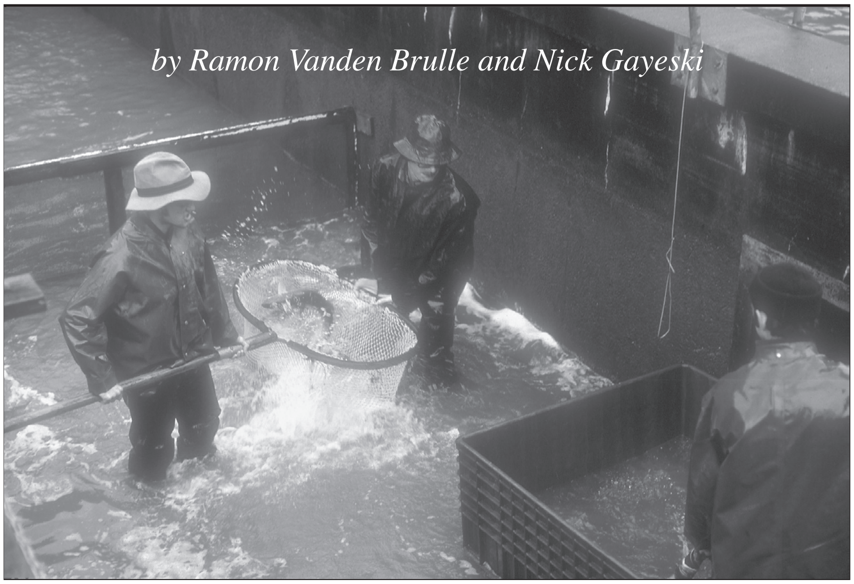
An Overwhelming Body of Evidence

How Hatcheries are Jeopardizing Salmon Recovery

by Ramon Vanden Brulle and Nick Gayeski



Hatchery personnel collecting returning fish for brood stock often injure or kill wild fish, both intentionally and unintentionally. Photo by Bill McMillan.

Hatcheries have been a part of salmon and steelhead management in Washington for more than a century. Originally, hatcheries were an articulation of a growing country's faith in technology and its own ingenuity, if an acknowledgement that the bounty of the closing frontier was not limitless. But no matter! If we canned salmon faster than they could reproduce, if we damaged their habitats through forestry, agriculture, and development, if we blocked their access to rivers with dams and other obstructions, we could simply make more. We would bring the ancient cycle of the salmon's birth, migration, and return into the American Century.

The fact that it wasn't working very well didn't seem to bother anybody. Even though the hatchery machine grew and expanded rapidly and steadily throughout the twentieth century, wild salmon and steelhead stocks declined at almost the same pace. In fact, it would turn out that the hatcheries themselves contributed to that decline. Even that bit of news, accepted today by virtually all parties involved, has not slowed the hatchery juggernaut. Today, over 130 state, tribal, and federal hatchery programs operate in Washington State. Over 300 hatcheries produce salmon and steelhead from California to Alaska. Meanwhile, 26 separate populations of salmon and steelhead have been listed as Threatened or Endangered under the Endangered Species Act.

A growing body of evidence and the overwhelming majority of the scientific community support the conclusion that hatcheries have damaged wild stocks, and that the problems associated with artificial production may be by and large intractable. In 1996 the National Research Council identified the loss of genetic diversity through hatchery production as a major factor in salmon declines, calling the loss of locally adapted salmon populations "the pivotal threat" to salmon conservation (*Upstream; Salmon and Society in the Pacific Northwest,* National Research Council, 1996). In 2001, the Bonnevile Power Administration's Independent Scientific Advisory Board told the National Marine Fisheries Service, "natural spawning by hatchery-reared salmon poses significant risks to wild salmon under most circumstances." Dozens of individual researchers and other scientific review panels, including NMFS' own Salmon Recovery Science Review Panel, have published similar findings.

Despite this prevailing view, hatcheries still have their proponents. Stakeholders, commercial, tribal, and recreational fishers, seem to have become addicted to the hatchery gravy train, and fight fiercely against any suggestion to scale back or eliminate hatchery programs. They believe that cutbacks in hatchery production could lead to diminished fishing opportunities, and indeed that is part of the problem: the production of large amounts of hatchery fish creates harvest pressures that commingled wild stocks — many in severe decline — cannot sustain.

Management agencies likewise appear to be reluctant to let go of the hatchery dream. Many continue to see value in artificial production as a band-aid to slap over the gaping wounds of overfishing and habitat destruction, or perhaps as a mask to help cover past and current management failures. Agricultural, forestry, development, mining, hydroelectric, and shipping interests view continued hatchery production as a potential way out from under land- and water-use regulations designed to protect dwindling wild-fish populations.

Of course the scientific evidence can't simply be ignored, and we hear a lot of talk these days about coming hatchery reform. Unfortunately, much of the talk is woefully short on specifics, and shorter on implementation, or even timetables. But a few hatchery programs are making attempts to avoid the transfer of individual populations between watersheds, to use locally adapted stocks for hatchery broods, to improve incubation and rearing techniques, and to try to reduce hatchery straying and other ecological interactions with wild fish.

Hatchery-reform proponents can wax enthusiastically about the purported successes of these few programs, citing increased hatchery returns and claiming that "new" hatchery fish are "genetically indistinguishable" from wild fish. However, many of the so-called reforms seem aimed more at improving hatchery performance rather than reducing impacts on wild fish, and successes often turn out to be exaggerated. The truth is that hatchery reform still begs more questions than it answers.

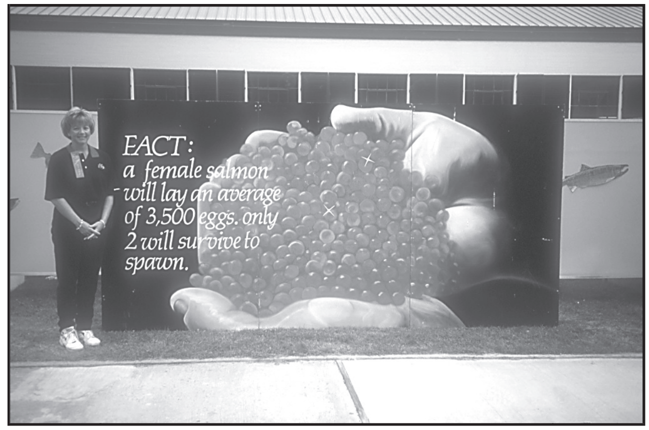


Photo by Kurt Beardslee

Hatchery proponents cite significantly increased incubation survival as a major benefit of artificial production. But this subversion of the natural selection process allows weakened genetic traits and poor survival adaptations to survive. When hatchery fish mate with wild fish, these poor traits can be passed into the wild population.

The Genetic Impacts

It is simply not true that hatchery fish are the same genetically as wild fish. They are the same species as the wild fish they are supposed to replace, and they can breed with the wild fish (up to a point), but there the similarity ends.

Hatchery fish have lower *genetic quality* than wild fish, for a variety of reasons, and with a variety of consequences. Hatchery fish suffer from what scientists call *domestication selection*. Hatchery fish adapt to pressures exerted by their environments just like wild fish do, but their environments are artificial (domestic) — usually with little relation to natural environments — and exert pressures that "select" fish to make them suitable for survival in that artificial environment. Domestication selection can happen both intentionally and unintentionally.

Hatchery rearing ponds with bird-exclusion nets. Allowing hatchery juveniles to feed and grow protected from natural selection pressures winds up "selecting" fish for survival in the domesticated environment, but with traits that are not necessarily well adapted to survival in the wild. Photo by Ramon Vanden Brulle.

Domestication selection can work behaviorally; i.e., hatchery fish are poor at avoiding predators because they are fed by hand in the hatchery, and don't "learn" to fear movement from overhead; in fact they are drawn to it. But it also has important genetic consequences. Poor breeding practices can compromise genetic diversity (the eggs of many females are often fertilized by a single male). However, improving breeding practices is unlikely to be of much help. There are several ways to mix eggs and milt among the total breeding population of a hatchery to maximize the genetic diversity of the offspring population. But none of these mimics selection of mates that occurs under natural conditions among unadulterated wild populations, and, therefore none of these hatchery mating-practices will produce (except perhaps by the remotest of accidents and then only on occasion) the functional genetic diversity among offspring that results from mating in the wild.

The main problem is more structural than that, and even less easily fixed. The main problem comes from the whole reason hatcheries exist in the first place: eliminating natural mortality from egg to smolt. In the hatchery, the survival rate from egg to smolt can be higher than 90%; in the wild it is generally well below 10%. Most, if not all of this surplus 80% would not be expected to survive in the wild under most environmental conditions due to their lower fitness (genetic quality). And the same thing is true of the remaining 10%. Lowered fitness in the post-hatchery environment is being traded against the greater numbers released from the hatchery as a result of this increase in egg-to smolt survival.

Among other things, this results in females that mature earlier (younger, smaller) and produce fewer eggs, and males that have fewer secondary sexual characteristics (like big kypes, exposed teeth, or large humps) that would help them compete with other males and/or attract females. These are clearly genetic characteristics. These differences create hatchery fish that have reproductive-success rates about 1/2 to 2/3 that of wild fish. This is all as fit, even when they come from native stock, even one generation-removed from the wild. No serious studies exist that dispute this.

Unfortunately, when released into the natural environment, hatchery fish are just as likely to breed with wild fish as with other hatchery fish. When hatchery fish breed with wild fish, they compromise the wild fish's reproductive success. Simply put, a wild salmon that breeds with a hatchery fish will produce fewer and less fit young than if it mated with another wild fish. Further, once hatchery fish do start breeding in the wild, there is virtually no practical way to monitor what effect the progeny they do manage to produce will have on the long-term health of the wild population.

Some significant recent analyses strongly suggests, however, that the negative genetic impacts on wild populations that breed with hatchery-reared fish may be profound, and irreversible on timescales relevant to ecological management. The negative genetic traits transferred into the gene pool of the native population may become what scientists call "fixed," that is inheritable from one generation to the next, thus continuing even after the hatchery program is discontinued, severely compromising the ability of the wild population to sustain itself. This can apparently occur even if wild stock is used for *every* generation of hatchery brood, and even if the hatchery population is a relatively small fraction of the overall population. The timescale to purge these genetic characteristics, or "alleles" from the native population is unfortunately likely to be longer than the timescale for extinction due to these impacts.

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Any two coho salmon, or steelhead, or Roosevelt elk, or humans, will have the same basic genetic structure, but *all individuals* of *any species* will display genetic differences. Some of those differences appear to be superfluous and benign — one of us is fair, the other dark. But some of them will have consequence — one of us is taller than the other. And some may not be benign at all – one of us has a distinct chance of developing diabetes. Hatchery and wild fish are genetically different; that is a proven fact. No responsible scientist or resource manager even tries to dispute it. The only debate possible is about what the impacts of those differences are, and whether and how those impacts can be adequately addressed.

Some behavioral consequences of domestication might be addressed by making changes to the way hatcheries are managed, but there's nothing behavioral about developing fewer eggs, or having a less pronounced kype or teeth too small to effectively compete for territory or a mate. Those consequences are clearly genetic, and apparently related to unnaturally high emergence-to-smolt survival in the hatchery environment. Simply making some changes around the edges of hatchery production, how fish are fed, what the rearing facilities look like, etc., is not likely to reverse or even reduce those consequences. Significantly lowering hatchery survival-rates could conceivably address some of these issues, but that would defeat the entire purpose of artificially propagating salmon in the first place. Trying to erase or minimize the consequences of domestication selection by using locally adapted native stocks appears to be ineffective, and in fact increases detrimental impacts when locally adapted hatchery fish are intended to spawn with the wild fish.

The Ecological Impacts

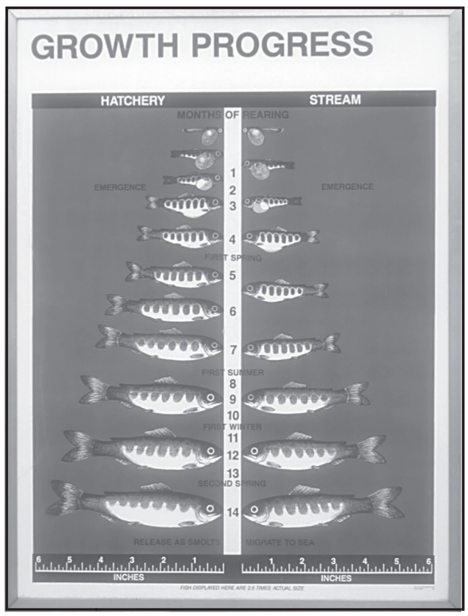
Competition between wild and hatchery-reared juvenile salmon or steelhead can occur in either or all freshwater, saltwater, and estuarine environments. Competition in freshwater can take place during rearing (feeding and sheltering) or during downstream migration to the estuary. In freshwater, saltwater, and estuarine environments hatchery salmonid fingerlings compete with wild fingerlings directly for food and/or preferred resting and hiding space, particularly when habitat space and/or productivity is limited.

Even though hatchery fish show overall lower fitness than their wild counterparts, over short periods of several weeks hatchery fingerlings are likely to be competitively superior to wild salmonid juveniles for several reasons, principally the size difference between the two. Hatchery juveniles are generally significantly larger than sympatric wild juveniles, and most competition for preferred habitat space among fish is determined on the basis of relative size alone. Secondly, as a result of rearing at densities much higher than wild juveniles experience and being guaranteed food regardless of behavior while in the hatchery, hatchery salmon are both more aggressive in competitive interactions in the wild and more tolerant of high densities. Third, during the initial post-release period hatchery juveniles are in better condition than wild juveniles. They do not pay high immediate mortality costs for aggressive behaviors that would have high mortality costs for wild juveniles. Relative size and condition, aggressiveness, and the tendency to move in dense groups result in most competitive interactions between wild and hatchery juveniles favoring hatchery juveniles. Hatchery juveniles can be expected to win most spatial competitions with wild juveniles in freshwater and during the first few weeks in the estuary.

Juvenile salmon and steelhead reside from two weeks to four years in freshwater habitats before moving downstream to saltwater. In large river systems salmonid juveniles reside and feed in a variety of habitat-types associated with banks and island gravel bars of main channels and in floodplain habitats connected to mainstem channels, such as side-channels and sloughs. Such habitats provide both food and protection from current and predators. In smaller rivers and tributary streams, juveniles rear in similar but smaller types of habitats.

Floodplain habitats in particular are generally more productive than main channel habitats that are available to small fish. In addition, the low current velocities and generally extensive cover in floodplain habitats are more energetically suitable to juvenile salmon and provide more efficient and less risky feeding opportunities.

Recent studies in Puget Sound and elsewhere in the Northwest have demonstrated that these critical rearing habitats have been greatly reduced and degraded during the past century by diking, draining, and the building of infrastructure related to agriculture and urbanization. With limited availability of off-channel habitats, wild salmonid juveniles are forced into suitable mainstem habitats, where they are forced to compete with hatchery juveniles for space and food. During at least some portion of this rearing period, the hatchery juveniles will exhibit relatively larger sizes and better condition, more aggressive behavior, and higher tolerance of increased densities, giving the hatchery juveniles a demonstrated competitive advantage over wild juveniles.



Hatchery juveniles display increased growth compared to wild fish, giving them a distinct competitive advantage and allowing them to displace their wild counterparts from preferred natural habitats.

In the main channels of rivers and streams, competition for low-velocity places that provide rest from the main current, for refuge from predators, and for shaded, deeper, more oxygenated, or otherwise more preferable habitats will result in the displacement of wild fish by hatchery fish, reducing the wild juveniles' probability of survival. Similarly, in preferred mainstem feeding habitats wild juveniles can be displaced by hatchery fingerlings. It is also likely that hatchery juveniles are displacing wild juveniles from limited resting and temporary feeding habitats during downstream migration.

The estuaries at the mouths of rivers are critical habitats for juvenile salmon and steelhead. For some salmon, particularly juvenile ocean-type chinook, it is the primary rearing environment where a critical amount of growth and metabolic change occurs that enable juveniles to develop the physiological capacity to live in sea water. All salmon and steelhead juveniles spend time in estuaries, ranging from a few hours up to 60 days.

At least some hatcheryjuveniles are spending at least some fraction of that period sharing and competing for these estuarine habitats with wild juveniles. While hatchery juveniles are generally released at sizes where they are capable of making a relatively swift transition to full saltwater environments, many will still be below the optimal threshold for efficient feeding and predator avoidance in open saltwater by the time they reach the estuary. At least some hatchery juveniles will take advantage of the low-salinity/low-stress environment, ample available cover, and feeding opportunities that the wild juveniles find so attractive in the estuary and associated near-shore habitats.

Recent studies have documented reductions in estuary capacity and habitat quality throughout the Northwest. Given the likelihood of interactions between hatchery and wild juveniles in estuaries and near-shore habitats, the competitive advantages exhibited by hatchery juveniles, and the documented reduction in estuary capacity, it is likely that hatchery juveniles are displacing wild juveniles in estuarine environments. Having to compete with larger, more aggressive, more density-tolerant hatchery bullies for reduced feeding and rearing opportunities within the estuary, during a period of already stressful metabolic change, is likely reducing the survival of wild salmonid juveniles.

As a general rule, salmonids can prey on other fishes that are one-third their length or less. Many hatchery plans cite this very rule of thumb. Yet many hatchery juveniles are released at sizes up to seven inches or longer, capable of successfully preying upon wild salmonid fry and fingerling up to 60 millimeters (2 1/3 inches), the average size of many wild juveniles during their freshwater life phases. Both predation and displacement of wild juveniles by hatchery juveniles is occurring in rivers and estuaries throughout the Northwest.

In virtually all of the rivers and streams where hatcheries release juvenile salmonids, returning hatchery-origin adults are known to stray onto the spawning grounds during the period of time that wild salmon are spawning. Many of these streams have documented proportions of hatchery adults on the spawning grounds ranging between 30% and 60% of all adults present.

Quite apart from the legitimate concerns regarding the genetic consequences of hatchery adults interbreeding with wild adults, hatchery and wild salmonids are clearly competing both for access to preferred nest locations and for access to mates. Regardless of whether wild or hatchery salmon are more fit or in better condition to endure the rigors of spawning, competition with hatchery fish is costing wild salmon energy, likely compromising their reproductive success.

Site Impacts

Unfortunately, the significant genetic and ecological impacts are not the only problems faced by wild fish from artificial production. Impacts from the hatchery facilities themselves often harm wild salmon and steelhead.

Most hatcheries are built directly adjacent to rivers and streams, often in the floodplain, and incorporate substantial filling and bank hardening in their construction. The loss of floodplain habitats and channel degradation from diking and bank hardening have been identified as limiting factors for salmonid production in many Northwest river basins. Many hatcheries also have fish passage barriers associated with the facility, either at their fish traps, or their water diversions. These barriers block adult fish from reaching otherwise suitable spawning habitat, or can block juveniles from reaching rearing habitats or accessing downstream migration routes.

Many hatcheries have improperly screened water-intakes, that can injure or kil adult or juvenile fish that are drawn into them. Leftover fishmeal, fish waste, antibiotics, and other chemical effluents are often discharged from hatchery facilities, degrading water quality. In fact many hatcheries throughout the region are routinely out of compliance with Clean Water Act standards. Hatchery rearing facilities are often efficient incubators of fish pathogens that can be released into the natural environment with infected fish or flushed into streams and rivers with other discharges.

When hatchery personnel collect returning fish during to harvest their eggs and sperm for brood stock, they often kill wild fish, sometimes intentionally, but often unintentionally because not all hatchery fish are marked, making them visually indistinguishable from their wild counterparts. May of these wild fish are listed under the ESA, making even their inadvertent killing illegal. Even when wild fish are identified and released during this process, they often die from the stress or injury of being handled.

The Political, Legal, and Management Implications

Under the terms of the ESA, regional management agencies must apply to NMFS for an exemption from ESA enforcement for any of hatchery program that could potentially impact a listed salmon or steelhead population. These applications would describe how managers will minimize the harm a hatchery does, and/or make the case for how its benefits justify that harm. If reform proponents are correct, and can offer a detailed case for justifying particular programs, they have the opportunity to present that case for public review. So far they have largely evaded that opportunity. While the applications have been overdue since January 2001, regional agencies have submitted applications for only a very small fraction of the hatcheries currently operating throughout the Northwest.

No matter what the ultimate intentions of hatchery-reform proponents, it is clear that the sheer magnitude of the problems with artificial productions and their impacts on wild fish will require a lot more than some adjustments on the margins. Often the attempt to remedy one problem exacerbates another.

For instance, attempts to reduce the genetic distinction between hatchery and wild fish by using locally adapted brood stock can increase straying and spawning interactions between wild and hatchery adults. Attempting to reduce competitive interactions by releasing hatchery juveniles at sizes that will encourage swift migration to saltwater can increase the potential for hatchery-fish to prey on smaller wild juveniles.

Meanwhile, political and legal developments are complicating the relationship between hatcheries and salmon recovery. In 2001, the so-called Hogan Decision in Oregon Federal Court de-listed Oregon Coast coho salmon, based on the way NMFS made distinctions between wild and hatchery-produced salmon. If the Hogan Decision stands, it could leave many other ESA listings vulnerable to similar legal challenges.

The Hogan ruling has been stayed while under appeal, but regardless of the outcome, the future status of ESA-listed salmon is uncertain. In the wake of Hogan, NMFS is reviewing de-listing petitions for 14 listed salmon and steelhead populations, re-drafting its hatchery-management policy, and re-examining the Status Reviews and listing decisions of each listed population. Opponents of responsible resource-management clearly see in the Hogan ruling an opportunity to circumvent ESA-protection for salmon, steelhead, and their ecosystems.

Over 100 years of the hatchery experiment has led to the inescapable conclusion that artificial production has been a significant factor in salmon and steelhead declines, and that it is scientifically incompatible with salmon recovery. It may now have become politically and legally incompatible as well. It is certainly clear that strong, credible environmental advocacy on hatchery issues will be necessary to successfully protect salmon and steelhead, as well as the broad range of habitats and organisms that will benefit from scientifically sound salmon-recovery policies.