HATCHERY REFORM: WHAT NEEDS TO BE REFORMED, THE OBJECTIVES, THE TECHNOLOGY, OR THE FISH?

Howard Fuss
Washington Department of Fish and Wildlife
600 Capital Way N
Olympia, WA 98501-1091

Abstract

Criticism of hatcheries has prompted serious efforts at reforming the way hatcheries are used and in some cases how the fish are reared. The use of hatchery technology to reverse trends in declining runs was logical in the early 1900s but no serious effort was made at evaluating hatcheries until much later in the century. The long wait was in part due to improvements in technology that spurred curiosity to evaluate the technology and the development of technology that allowed for better evaluation. As a result, advances in hatchery rearing practices and equipment demonstrated that improved survival could occur as well as providing baseline time-series evaluations of survival at some hatcheries. Unfortunately, change in the objectives of many hatchery programs and how hatcheries are viewed in the context of ecosystem management has been slow to evolve. In recent years, because of listings of salmon under the Endangered Species Act, reforms are being developed and implemented at Washington Department of Fisheries Hatcheries that will change production goals to some extent. However, political and social issues will always influence production goals, so operating hatcheries under an ecosystem context will require the backing of agency managers, commission members, co-managers and the support of the legislature. The future can be bright for the coexistence of hatchery and wild production as long as the mistakes of the past are not repeated over time.

Introduction

Salmon hatcheries were used in the early 1900s for two primary purposes: to boost commercial harvest levels after catch of natural-origin salmon had declined, and to replace adult fish production lost or likely to be lost as a result of habitat loss and degradation. Natural-origin salmon returns declined because of over-harvest in fisheries and as a consequence of man's competitive use of land and water resources critical to salmon.

Whether the causes behind these early dwindling runs were well understood or accepted, the idea of a relatively inexpensive technological fix appealed to those who made the decisions. And why not? The new technology promised that a larger percentage of each female's eggs would survive to the fry stage, and the logic clearly indicated that more fry would mean more adults. Many years later and after millions of research dollars have been spent on improving the survival of hatchery salmon, we can see why this logic failed. The hatchery programs in those days did not include any monitoring and evaluation. Either catch increased or it didn't - an outcome that served as the lone standard for measuring program success. Now we know that transporting and transferring stocks reduces survival, that stocking fish at the fry stage instead of as larger, older fish, reduces survival. We also have learned how to grow fish larger and in less time, what the effects of rearing density are on adult yield and survival, the effect of release date on survival and size at return, where the fish migrate in the ocean and in what proportion they are caught in various fisheries. We know that survivals fluctuate annually and are largely affected by ocean conditions and river flows, and the number of avian and fish predators, but can also be affected by the degree to which fish have been exposed to pathogens. We have learned that we can raise fish in seawater pens and that these fish will stray much more than fish reared in freshwater facilities. We know that hatchery fish tend to migrate rapidly downstream after release, but we also know that in some instances these fish, should they remain in the river, may be overly aggressive or predatory, thus harming the wild fish. As the result of this broad spectrum of research, many hatchery practices have been changed or modified over the years, yet there are still socio-economic and legal factors that influence both hatchery practices and hatchery production.

We recognize that recreational fisheries focused on hatchery origin fish generate millions of dollars in revenues to the various states and provide countless hours of enjoyment to citizens. It is also clear that our elected political officials love to make their constituents happy, and the level of juvenile production at hatcheries in their jurisdiction is considered success, but agencies have also implemented new fish rearing measures that we know work in most years to increase survival of the hatchery fish to adult return. These long-practiced, new, and evolving measures, derived from our collective years of experience, tinkering, and application of what we view as "best available science" are now popularly categorized as "hatchery reform" measures. With the advent of ESA listings of some important salmon stocks in the Pacific Northwest, the funding of old and new hatchery reform measures has become more urgent to our leaders as a potential way to continue to efficiently produce salmon for harvest, but to do so in a way that poses low risks to wild salmon populations. Use of hatcheries as a potential means to preserve and restore wild stocks has also become an objective of hatchery reform and its funding. So now that money is being spent on hatchery reform, just what is it about hatcheries and the way they are operated that needs reforming?

Many uncertainties surrounding hatchery production still exist. Can hatcheries be used to restore wild runs of salmon using the same technology that has been criticized by some as being ineffective in the first place? Do fish raised for many generations in the hatcheries suffer from domestication selection and does this make them unsuitable for reproducing in the wild? Does exposure to the hatchery for even one generation change the fish enough to make them ineffective for establishing or bolstering wild returns? Are there methods that can be used in the hatchery to make these fish equivalent to wild fish; genetically, behaviorally, and reproductively? Is the infrastructure of the hatchery changing the river environment to the detriment of wild fish of all species? These are just some of the questions that must be answered.

Hatchery reform suggests change or improvement, yet what is it that needs changing in the hatcheries? Is the technology and culture used to raise the fish inadequate? Are the production and species goals of the hatcheries outdated or incompatible with current production needs? Are the fish inadequate? Or does the entire infrastructure of hatcheries need reforming? What follows is a discussion of the technological changes made in hatcheries over their history and some of the challenges that still remain, the objective of hatchery production and how that fits in the new world of protecting listed species and a discussion of the fish themselves and whether they are capable of fulfilling the expectations of those that want to use them in recovery actions.

Technology

The history of Washington state hatcheries began in the late 1890s in response to dwindling commercial catches of salmon. The technology of hatcheries was attractive because of their ability to protect eggs and alevins from exposure to natural factors that severely limit survival of wild fish in their earliest life stages (e.g., flooding, predators, drought) to yield a greater number of progeny per female than in the wild. However, the resulting fish were typically stocked as fry and may have been stocked in areas of streams not conducive to fry survival. Later, rearing containers were constructed that allowed fish to be reared to a larger size, using primitive feeds to grow the fish. However, often these feeds led to disease problems and because little research was done on the proper size and date to release the fish, the success of these programs was likely similar to the success of the original fry planting programs- especially with species that we now know require extended rearing. In the late 1940s pelleted feeds were developed and in the early 1950s, biologists and pathologists began to formally meet to discuss hatchery issues. Not much later, research led to the development of the Oregon Moist Pellet, which allowed culturists to successfully rear more fish to the yearling stage and release chinook at larger sizes during their normal migratory period. And not surprisingly, species that were previously not reared successfully at hatcheries like coho salmon, began to return in greater and greater numbers.

The technology that led to the ability to increase production also spurred the development of other new technologies, including the development of incubators, rearing techniques, diets, improvements in nutrition and disease treatment. And with the concurrent development of the coded-wire tag in the late 1960s, all of these changes could now be more precisely measured using sound scientific protocols. Differences in survival due to size or date of release could be measured and the distribution of various stocks of salmon could be mapped. The effects of rearing parameters such as density and flow rates in various types of rearing containers could be measured in terms of adult survivals and yield to the fisheries. Modifications to incubation containers, better use of water at hatcheries and better treatment of pathogens and parasites, and the addition of rugose substrates were all developed in the last 40 years. Thus, a whole new era in evaluating hatcheries was born.

However, funding for these evaluations was sporadic and often done in a manner that would not allow consistent, if any, measures of hatchery efficacy. For example, no coded wire tagging program over 5 brood years in length has ever been implemented in Puget Sound or coastal hatcheries to assess annual survival and contribution. The only funding source available for these two areas comes from the state general fund and neither the legislature or the Washington resource management agencies have ever appropriated money for the purpose of long term hatchery evaluation. Thus, survivals and contribution rates at Puget Sound or coastal hatcheries must be done by estimating these parameters from a few coded-wire tag groups that are likely released for other research purposes. The bottom line is that WDFW cannot answer seemingly simple questions about how well their hatcheries are doing. In contrast, hatcheries on the Columbia River receive funding from the Bonneville Power Administration to evaluate each year's production of chinook and coho from each lower Columbia River hatchery which receives federal funding for operation. Since 1990, survival and contribution trends for each species can be assessed. This has led to important findings, including the dramatic decline in the number of adult coho produced per 1,000 smolts released, from an average of 26 in the 1980s to less than 2 during the El Nino affected years, 1991 and 1992 (Byrne et al. 1998). Other information critical for effective hatchery management is provided by this program, including hatchery fish stray rates among watersheds. It is important to understand that without these types of evaluations, the efficacy of hatchery technology and any biological changes in the fish themselves cannot be assessed, and if they are not known they cannot be changed.

Hatchery goals

Actual annual hatchery production levels by species are determined by legal agreements between the state and Tribes, who co-manage the salmon resource consistent with Treaties and Federal Court Orders. Production levels are also driven by politics, and more recently by the urgent need to respond to wild fish protective requirements inherent with ESA listings. The basis for these production agreements is often benchmarked at maximal production levels because it is often thought that more juvenile fish means more adult fish, which then translates to maximum harvest opportunity or completely meeting mitigation objectives. This way of thinking is very similar to that which occurred in the early history of hatcheries. Thus, too often the success of an individual hatchery is measured by how close juvenile release figures match the established production goal. Of course, without adequate means of evaluating how many fish are actually released, the achievement of production goals are somewhat superfluous. Often, attempts at developing and evaluating goals are abandoned due to insufficient funds. An example of this is the now defunct initiative that led to the development of WDFW's, "Hatchery Operations Plans and Performance Summaries (HOPPS)" (Fuss and Ashbrook 1995). The brief life of the HOPPS process of evaluating each hatchery annually was due to insufficient state funds. Furthermore, the work unit within the hatcheries division which was responsible for developing the HOPPS documents as well as evaluating and developing new hatchery techniques was completely eliminated for lack of funds. This illustrates one of the key issues necessary for effectuating hatchery reform: Providing adequate funds to evaluate hatchery performance, develop or test new technology and make appropriate operational changes where necessary.

Two such processes were initiated with the 1999 ESA listings of Puget Sound chinook. Subsequent to the listing, Washington state, the treaty tribes and the federal government started a detailed review process that led to development of hatchery management implementation measures. Included in the review process was the development of Hatchery and Genetic Management Plans (HGMP) for each hatchery to thoroughly describe each program and to identify data gaps regarding hatchery performance and effects. WDFW also implemented the Biological Risk and Assessment Process (BRAP), which is a modeling tool used to consistently evaluate hatchery impacts to wild fish and remedies. Both reviews seek to provide guidance to minimize risk to listed species.

In 2000, money was appropriated by the federal government for the purpose of hatchery reform that led to the creation of the Hatchery Scientific Review Group (HSRG), an independent panel of scientists representing state, tribal and federal agencies with several independent scientists appointed at large. Through the HSRG, federal money is provided specifically for hatchery evaluations, ecological evaluations, and hatchery retrofitting. Both the HSRG and the ESA review process have provided a ray of hope that at least some hatchery programs will be scrutinized beyond the single purpose of producing fish. To date the HSRG has made three "Area Wide Reviews" that incorporate the following recommendations for hatchery programs within watersheds: 1) Take a regional approach to managing programs; 2) Operate hatcheries within the context of their ecosystems; 3) Measure success in terms of contribution to harvest and conservation goals; 4) Emphasize quality, not quantity, in fish releases; 5) Incorporate flexibility into hatchery design and operation; 6) Evaluate hatchery programs regularly to ensure accountability for success; 7) Develop a system of wild steelhead management zones; 8) Use in-basin rearing and locally-adapted broodstocks; 9) Take eggs over the natural period of adult return; 10) Develop spawning protocols to maximize effective population size; and 11) Take into account both freshwater and marine carrying capacity in sizing hatchery programs.

Using the results from the BRAP analysis, some major changes in hatchery operations have already occurred, such as elimination of seawater net-pen rearing to reduce straying of hatchery fish. However, other issues still need resolving, such as the elimination of out-of-basin steelhead stocking programs that return only a few fish to the creel each season but which cost tens of thousands of dollars to produce and deliver the fish. Other recommendations will include providing better passage around hatchery barriers so that native salmonids and other species have access to all stream reaches, and replacing screens on intakes to prevent accidental capture and entrapment of newly emerged wild fry. These are just a few of the current and projected changes that will occur to reform hatchery practices.

The fish

Depending on the source, hatchery fish have been labeled as dim-witted mongrels, or perfectly fine replacements for wild fish. But the question of to what degree exposure to the hatchery changes the biological characteristics of the fish still remains largely unanswered (Busack and Currens 1995). If behavioral or genetic changes have occurred, are they enough to make the fish unfit for natural reproduction? But to answer this question it is first important to define what a hatchery fish is, because it has been popular in both scientific and lay circles to characterize all hatchery fish as having the same attributes. However, there is a wide range in the type, quality and purpose of hatchery fish. For instance, chum salmon fry are reared for only a few weeks before release and then spend over 90% of their lives in the wild. On the other end of the spectrum are trout reared for 1-2 years in the hatchery and released in lakes for put and take fisheries. Since about 1985, hatcheries have been identified as potential tools for recovery of depressed populations either through captive brood programs using native stocks or supplementation programs. As the name implies the captive broodstock are reared for their entire lives in the hatchery but a portion of their progeny may be released to the wild. In supplementation programs, progeny of indigenous-origin stock may be reared to smolt size before release to the wild. The expectation of the performance in each of these types of hatchery program needs to be understood in terms of the differences in fish quality, cost and benefit, and how the fish are reared to achieve the product. Would we expect a domesticated trout broodstock to be more successful in establishing a self-sustaining natural population than a broodstock developed from the native population? The answer to this question actually depends on many factors besides how the fish are reared.

For example, a natural population could be re-established from by hatchery fish if they retain fitness traits essential for re-adaptation to the wild. Even if a population originates thousands of miles away from the intended water to be stocked, individuals within the population may possess the appropriate fitness traits suitable for adaptation to their new environment. Several examples have been documented, including the establishment of self-sustaining Pacific salmon populations in the Great Lakes and New Zealand, or the establishment of naturally reproducing populations of trout in previously barren alpine lakes as a result of hatchery stocking.

Critical to recovery of depressed populations is determining the reproductive success potential of stocks that have had some level of exposure to hatchery rearing. Several studies are currently underway to address this issue and some of these will be briefly described below. Although the final results of these studies are pending, preliminary results may be used to guide managers in answering important questions, such as whether hatchery fish are responsible for the creation or maintenance of several existing natural populations. The results of these studies may also be used to address our on-going uncertainties regarding the need to adjust hatchery practices to modify post-release behavior of hatchery fish so they perform more like wild fish. The following discussion will focus on some examples of studies and results currently underway to address these uncertainties.

Deschutes fall chinook study: Deschutes fall chinook could be considered a highly domesticated southern Puget Sound hatchery stock. The Deschutes River historically lacked a natural population of chinook salmon, due to an impassable falls at its mouth. A fall chinook return was introduced through repeated introductions of Green River-origin fall chinook beginning in the late 1940s. Fall chinook have been reared at the Green River (now Soos Creek) hatchery, and used as a seed stock for introducing fall chinook returns in other Puget Sound watersheds, since the early 1900s. The sole purpose of establishing a hatchery run in the Deschutes River was to create and bolster sport and commercial fisheries. The Tumwater Falls Hatchery (TFH), located on the lower Deschutes River (which includes Capitol Lake at its juncture with Puget Sound), is primarily an egg collection and final rearing and release facility. Eggs collected from returning adults are transported to hatcheries in other watersheds where they are hatched and reared for several months before return to the Deschutes River Basin for rearing and release. Because the rearing capacity of TFH is limited, many types of rearing scenarios have been used over the years to expand fish release levels. They range from the stocking of Capital Lake with fry (for natural rearing until the smolt), to rearing of yearlings in net pens located in a cove of Capital Lake. Recently the adult collection ponds are used to rear fish for 2 weeks prior to release; at least 5 groups of 900,000 fingerlings are released from this facility from April to June. And in years when the egg collection is inadequate, genetically similar stocks may be brought in from other facilities to backfill egg shortages. For several years, hybrids of spring and fall chinook were released from the facility.

Because of the obvious potential for this introduced stock to have become highly domesticated and maladapted to survival on its own in the natural environment over the 55 years that it has been under propagation, and because there was originally no natural population of fall chinook in the river, we instigated a multi-year study to determine:

1) Reproductive success of returning F_1 hatchery origin and F_2 natural origin fish that were passed upstream of the normal hatchery broodstock collection site to spawn naturally in the river, as measured by egg to smolt survival and smolt to adult survival; and 2) Maintenance of certain fitness traits that may influence

reproductive success.

Two broods of adult chinook have been passed upstream to spawn. The reproductive success of the first brood was 12.6 % based on the estimated number of females that spawned (800), their average fecundity (5,200 eggs/female) and the estimated number of resultant emigrating fry and smolts that were collected near the mouth of the river (152,000). The success of this brood may have been due to the low river flows that occurred throughout the spawning and incubation period. The 2001 brood did not fare as well. Of the estimated 349 females that successfully deposited eggs (4,651 eggs/female) it appears that fewer than 30,000 fry or smolts will be captured (2.0 % reproductive success rate). The poor success in 2001 was likely due to several high flow events that scoured eggs incubating in the gravel. Several more broods of F_1 hatchery origin adults will be passed upstream before the first returns of natural origin (F_2) adults produced through this study. The second phase of the study is to determine if the natural origin progeny maintain certain fitness traits such as diel migration, ability to grow in the stream, typical downstream migration timing and response to physical factors that affect this timing. We plan to compare these traits to those possessed by juvenile hatchery reared fish released during the spring. In the 2000 study, we found that 86% of the total downstream migration of natural juveniles occurred by April 1, and was comprised of fry smaller than 50 mm in fork length. The remaining 14% of the emigrating juvenile chinook population that year consisted of fish that ranged in size from > 50 mm in April to over 100 mm in June. Chinook emigrated primarily at night (86 %) and mostly during the waxing and waning phases of the moon. Very little migration was observed during the brightest phases of the moon. The migratory traits that we observed for naturally spawned chinook salmon juveniles in the Deschutes River study have been reported for wild populations as well (Healy *in* Groot and Margolis 1991). In contrast the concurrent releases of hatchery chinook juveniles resulted in large numbers of emigrating fish over short periods of time. Although most of these fish migrated at night a much larger percentage than the wild fish migrated during the day. Because of the short time interval of the migration past our trap it appears that the hatchery fish did not use other environmental cues- rather they just moved downstream immediately. It will be several years before we can measure the smolt to adult survival of either progeny of hatchery fish reared in the hatchery or in the wild. Nonetheless, it does appear that even in this stock of potentially domesticated fall chinook, many of the traits associated with survival in the wild are still possessed by those that originate in the wild.

<u>Reproductive success studies</u>

Two similar, but more complex reproductive success studies, are being conducted by WDFW, in collaboration with NMFS. The first compares wild and hatchery origin coho spawning and productivity in the wild at Minter Creek, and the other compares the same traits for a hatchery broodstock developed from wild summer-run steelhead and the wild fish spawning naturally. Each study uses DNA pedigree techniques to determine the reproductive success of pure hatchery, pure wild and hybrid crosses in the first and succeeding generations. Only juveniles have been sampled thus far in the Minter Creek study. The first return of adult steelhead is expected this summer on the Kalama River and subsequent juvenile sampling will begin in 2003. Pedigree analysis, matching fry to parents, was successful at Minter Creek and indicated a slightly higher proportion of progeny from pure hatchery crosses than pure wild crosses. Smolts from the first brood are also being sampled during out-migration in 2002 and a similar analysis will occur. The first return of jack coho resulting from the Minter Creek study will be evaluated this fall, with the first adult returns expected in 2003.

Have hatchery stocks created or maintained wild runs?

Unfortunately, data are sparse and somewhat ambiguous on this question. The main drawback to ascertaining the validity of claims that runs were started with hatchery fish is that the hatchery fish were not marked, and therefore indistinguishable from potential wild spawners, even if the latter would have strayed in large numbers to the system in question. Furthermore, several other studies introduced non-native hatchery stocks with different timed spawning than the native stocks and introduced these fish into areas where the native species was present. The result of no net increase in adult returns might be expected if the introduced stocks did not possess life history traits amenable to their new environment, or if the introduction of the hatchery fish displaced the wild juveniles or wild juveniles displaced the naive hatchery reared fry.

In Washington there are three examples where the removal of impassable barriers to upstream migration and the stocking of hatchery origin salmonids led to the establishment of natural runs to the previously inaccessible areas of the river. On the South Fork Skykomish River, coho, summer steelhead and a few chinook were stocked upstream of Sunset Falls a natural barrier to fish migration. Adults were enumerated beginning in 1958 and since that time the average return of coho, chinook, and summer steelhead has been 14,561, 628, and 602, respectively. Because the first two species are native to the system and because the stocked hatchery fish were not marked, it is not possible to rule out stray wild fish from having colonized the area. However, summer steelhead are not native to the system, and, it appears that hatchery origin fish are responsible for the establishment of the natural run of summer steelhead on this river. A similar example exists on the South Fork Stillaguamish River, but again, stray fish native to the watershed could have colonized the newly accessible portion of the river.

The one example of a successful introduction of coho occurred on the Deschutes River in southern Puget Sound. Prior to construction of fishways in the lower river, no coho were found in the river above the falls. The river was stocked for several years beginning in the1940s, prior to the completion of the fishways in 1952. In 1953 a handful of coho were enumerated but with repeated stocking throughout the 1950s and early 1960s, the average return of coho grew to several thousand fish annually. Since 1980 the annual return of coho has consisted entirely of wild origin fish and escapements to the river have averaged 3,320 fish. However, declining habitat and poor ocean conditions since 1989 have reduced annual escapements to 864 fish. The likelihood of stray fish colonizing the newly opened habitat is low in this case because only a few small streams are found within proximity of the Deschutes River.

Several reviews have suggested that out planting of hatchery origin fish have had a neutral to negative effect on existing wild populations (e.g. McGie 1980; Solazzi et al. 1983). However, in nearly every study there are several variables not controlled: 1) Genetic and associated life history trait differences; 2) Differences in size of hatchery and wild fish at introduction which could lead to competitive advantage favoring the larger fish; 3) Habitat carrying capacity was not established; 4) The method of stocking hatchery fish into wild habitats was not evaluated for it's effect; and 5) No determination was made whether the genetic mark fostered in the hatchery fish population led to deleterious effects on their survival.

Can hatchery fish be more "wild like"?

More recently, research has focused on enhancing the standard hatchery rearing environment by adding complexity to the rearing containers. The idea is to provide the hatchery reared fish with more life skills, more complexity and the opportunity to better develop cryptic coloration which may protect them from predation after release. As reported in several studies (Berejekian 1995; Fuss and Byrne, in press; Maynard et al.1996) increased smolt to adult survival rates have been demonstrated for smolts reared in enhanced environments. However, adult yields are likely reduced relative to the status quo hatchery release programs because of the lower rearing densities used in these studies (Fuss and Byrne, in press). Several studies are currently being conducted using rearing scenarios that are more reflective of the generally high fish production levels needed to meet regional hatchery adult return objectives. In nearly every previous study, the fish have only been subjected to the enhanced environment for a relatively short period of their entire rearing experience. Most fish are reared under standard conditions for a period of time before being exposed to the enhanced, more natural environment. I am proposing that producing hatchery fish that are truly more "wild like" requires a more comprehensive approach than the partial experience given fish in these experiments.

I base my hypothesis on the result of work done by neuroscientists on the development of the brain in animals and humans. The major difference that exists in brain development of juveniles and adults is that the brain is much more plastic (impressionable) in juveniles than adults. The positive side of this plasticity is that the brain of a juvenile is more open to learning and enriching influences than the adult brain, but the down side of this is that they are also more vulnerable to developmental problems if their environment is impoverished or un-nurturing. I believe that differences in survival of hatchery reared fish and wild fish are not necessarily genetic. Rather, both groups have the same basic wiring plan for forming neurons and general connections between different brain regions. However, the experience each group receives and when that experience occurs is responsible for fine-tuning those connections. Experience excites certain neural circuits while those rarely excited during the critical period of brain development are "pruned" and do not function in later life. This forms the basis for the hypothesis that "cells that fire together, wire together". How might this be applied to the environments of hatchery and wild fish? A comparison of the two environments provides insightful differences. Alevins in a natural gravel environment experience low levels of light, low interactions with their siblings, and a rugose environment that fosters efficient use of their yolk sac for development and growth, rather than on metabolism. In contrast, hatchery alevins are concentrated in greatly restricted confines during incubation. They react to more frequent exposure to light and they spend more energy attempting to right themselves. Resultant, increased use of their limited yolk sac reserves for metabolic purposes may stunt their growth and perhaps delay development. Upon emergence, wild fry are subjected to lower densities with cohorts, a complex environment of different shades, patterns, substrates and light. They must begin to ascertain what food is by sampling many different shapes and textures and they must do so under fairly constant threat of predation. Hatchery fry are reared by the thousands in blue colored troughs or by the hundreds of thousands in steep sided and deep concrete vessels. The food they receive is uniform in size, shape and color and is presented on the surface of the water and associated with the movement of humans or vehicles. As fry grow in the wild they respond to differences in temperature, flow and habitat preference. They exhibit different types of behavior during the day and night and change their food preferences seasonally. During that same period of development, the hatchery fish are growing but mostly in the same environment they have always known. They may be moved to different rearing vessels but they spend a large amount of time in these new vessels before release. Wild fish that overwinter are faced with greater challenges to survival than hatchery fish that overwinter. The wild fish must find suitable habitat to escape high flows and turbid water, whereas the hatchery fish deal only with the turbid water and in some cases with very little turbidity or temperature fluctuation during the winter. Lastly, the wild smolts must migrate downstream using flow, temperature and photoperiod to guide them on their journey. In contrast the hatchery fish experience stream life for the first time and must make all the adjustments that the wild fish have already learned to make in just a short period of time after they are released. Thus, if the fish's brain is developing throughout these series of life changes it stands to reason that hatchery fish may not form important neural synapses in time to develop behavior patterns that are beneficial to their survival. If this is the case then to truly produce a "wild like" fish in the hatchery will require considerable reform in hatchery rearing practices, starting from when the fish hatch and concluding at release.

Conclusion

Hatchery reform must use a multi-dimensional approach because many of the problems that face wild salmon today are not caused by the hatcheries themselves but rather how and why the hatchery is being used. There are several important changes that must be incorporated and within Washington State some of these are already occurring and were discussed above. Perhaps the single most important reform that must take place is in how hatcheries are viewed and how those views affect decision making processes. Hatcheries can be fish factories and pump out millions of fish, and may be perceived as success by some. In terms of technological achievement maximal production of healthy fish at release is a success. However, this attribute has long been associated with the general philosophy that all fish are essentially the same. We know that all fish are not same and improvements in technology at hatcheries must be made with improvements in managing the biology of the hatchery fish. Selection in the hatchery that eliminates the natural traits of the fish should be eliminated for any stock that co-mingles with wild fish. Furthermore, in cases where fish are expected to behave like wild fish, they should be given the opportunity to learn like wild fish. I believe this may need to occur earlier in development than previously addressed.

Two other goals identified in the HSRG review, "Take a regional approach to managing programs and operate hatcheries within the context of their ecosystems", will require acknowledgment that specific production objectives will have to be developed for each hatchery and reflect the goals of restoration, protection, and harvest within the particular region. Furthermore, objectives and goals of the hatchery must be uniformly understood at all levels of influence - from the resource managers down to the hatchery culturists. Two other recommendations from the HSRG should be mandatory in the objectives of each hatchery's production levels: "Measure success in terms of contribution to harvest and conservation goals and emphasize quality, not quantity, in fish releases". If fish quality factors such as genetic make-up, or behavior and performance after release, are not goals of hatchery programs then hatcheries cannot be operated within the context of the ecosystem unless the ecosystem consists of only hatchery fish. Hatcheries used in supplementation or recovery programs must not be operated as just fish farms. Rather the hatchery product should reflect the entire suite of phenotypic and genotypic traits of the stock. If these traits are maintained then the fish have lower risk to the wild stocks. Although political and social issues will always determine production goals to some extent, it is paramount that the goals of hatchery production, defined locally or in context of the ecosystem, have the backing of agency managers, commission members, co-managers and the support of the legislature. The final issue that needs to be addressed in hatchery reform is the funding of research and in routine monitoring and evaluation of hatchery programs. Funding for research needs to be aimed at addressing the critical uncertainties that still exist with hatchery production and operations, and how or if that production can co-exist with wild production. Monitoring and evaluation of hatchery efficacy is essential to determining if the cost of operating the hatchery is commensurate with the benefits of operating individual hatcheries. The cost : benefit ratios of each type of rearing program will differ and policy makers must understand these differences to maintain continuity of evaluation.

The future can be bright for the coexistence of hatchery and wild production as long as the mistakes of the past are not repeated over time.

Acknowledgments

My thanks go to Tim Tynan and Dr. Craig Busack for their help in preparing this manuscript. Also I want to acknowledge the Hatchery Scientific Review Group and the National Marine Fisheries Service for providing funding for several of the studies mentioned in this manuscript. Lastly, many thanks go to my colleagues at the Washington Department of Fish and Wildlife for their assistance in performing

research on hatcheries and the many hours of lively discussion on the topic of hatcheries.

Literature Cited

Berejekian, B.A. 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (Oncorhynchus mykiss) to avoid a benthic predator. Canadian Journal of Fishery and Aquatic Science. 52: 2476-2482.

Busack, C.A. and K.P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. American Fisheries Society Symposium. 15: 71-80.

Byrne, J., H. Fuss and C. Ashbrook. 1998. Annual coded-wire tag program Washington-missing production groups. Annual report, U.S. Department of Energy, Bonneville Power Administration, Project number 8906600. 107 p.

Fuss, H. and C. Ashbrook. 1995. Hatchery Operations Plans and Performance Summaries. Volume 1 (2): Puget Sound. Washington Department of Fish and Wildlife, Annual Report.

Fuss, H.J. and J. Byrne. *In press.* Differences in survival and physiology of coho salmon (Oncorhynchus kisutch) reared in a semi-natural rearing pond and a conventional hatchery-rearing pond. North American Journal of Aquaculture.

Healy, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*) *in* C. Groot and L. Margolis *eds*. Pacific Salmon Life Histories. UBC Press, Vancouver, BC. 564 pp.

Maynard, D.E., T. A. Flagg, C. V. W. Mahnken and S.L. Schroder. 1996. Natural rearing technologies for increasing postrelease survival of hatchery-reared salmon. Bulletin National Research Institute of Aquaculture, Supplement 2: 71 - 77.

Sollazzi, M.F., S.L. Johnson, and T.E. Nickelson. 1983. The effectiveness of stocking hatchery coho presmolts to increase the rearing density of juvenile coho salmon in Oregon coastal stream. Oregon Department of

Fish and Wildlife, Information Reports (Fish) 83-1, Portland, Oregon.

McGie, A. M. 1980. Analysis of relationships between hatchery coho salmon transplants and adult escapements in Oregon coastal watersheds. Oregon Department of Fish and Wildlife, Fish Division, Information Report Series, Fisheries Number 80-6. 19 pp.