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THE PLIGHT OF THE HATCHERY FISH: IS IT ALL GENETICS?

In all fields of science, if there are opposing conclusions to the same questions, the question is not answered. What went on in one study in one river or hatchery may not necessarily apply to all rivers and all hatcheries.

The author with his grandsons and son-in-law volunteering at the local hatchery.

Most of my friends are fishermen or fisherwomen. Besides fishing, we also volunteer time at the local hatchery spawning fish, both steelhead and fall Chinook. We always hope a significant percentage of these fish will return someday as adults to create fishing opportunity for us and future generations of fisher people. We see and handle these fish. We know they are a quality product from our efforts in combination with a thousand years of genetics within the nucleus of their cells. I am not a fisheries biologist but do have a background in genetics. In my previous employment with the Oregon State Police, I did genetics testing on humans and on big game. My results on the research in big game genetics were published in a peer reviewed journal.

When the topic of hatchery fish comes up in the media, the conversation often migrates to fish genetics. People talk about fish genetics but often do not understand the basic concepts of genetics and how it might relate to a fish. This includes how it might relate to hatchery fish and their counterparts, the natural spawning fish in the same watershed. What is fact and what is belief is important. Do not kid yourself, researchers can be as political or biased in their beliefs as anyone else.

The most significant genetic event in the life of a fish is the fertilization of an egg by a sperm. These reproductive cells each carry half of the genetic codes of each parent, so the final product does not end up with too many chromosomes. However, in the development of each reproductive egg, the inherited genetic codes are slightly different from one fertilized egg to another. The offspring are going to end up looking like the parents, but they will not be exactly like either parent. One look at your brothers and sisters confirms the differences in inheritance from the same parents. Of course, identical twins are the exception. The diversity of offspring is important to the evolution of a species when at times, the slight differences may not be visible. If you are an antelope on the African Savanna and inherit a combination of genes that allows it to outrun a lion, that antelope might get a chance to pass on its gene combination to its offspring. Thus, giving the offspring the same advantage. The antelope at the back of herd that did not have that gene combination may get eaten and those genes do not get passed on. This is evolution or survival of the fittest. Fitness of anadromous fish is just as important. As the rivers, seas and climate change, those that can change with it survive.

Genetic Bottlenecks

Another fish relevant circumstance is called a genetic bottleneck. Genetic bottlenecks have happened with a number of species, the buffalo being a common example. Buffalo populations dropped from the millions to a couple hundred before herd restoration began. Bottlenecks with fish can happen on both a large and small scale. On a large scale, humans historically gill netted salmon on coastal streams all over the Northwest. Eventually only a small population of anadromous fish remained compared to the size of the original population. There were stories of Chinook Salmon weighing 100 pounds in the early days on the Columbia. Those genes are gone forever, but from the remaining group, we have our current salmon populations. To offset this area wide population decline, historical records show eggs fertilized in hatcheries primarily on the Columbia, were transported by humans all over the coast to restore threatened populations. With the transport of those fish went the historic genetic data from the original river source to other rivers throughout the Northwest. These new fish went on to repopulate the runs in those watersheds, a testament to their adaptability. In Coos County, there are no original native populations of anadromous fish. Fisheries biologists use the term "locally adapted" to describe the current anadromous fish populations. What native populations were not eliminated by gill netting in the 1800's, were struck down again by splash dam logging in the early 1900's. These log dams were up to fifty feet high and blocked the rivers until release sending the logs down the river killing most living creatures along the path. In the 1950s, for example, stream surveys only showed a handful of fall Chinook had survived to spawn in the South Coos River. A 1972 study by ODFW indicated only 500 fall Chinook remained in the Coos system. Hatchery supplementation restored the runs. It is ironic those supplemented runs that are present today are often called "native" or "wild". These fish simply do not have a clipped adipose fin. Adding to the confusion, hatchery raised fish derived from this brood stock are now considered to be a genetic detriment to the locally adapted "native" spawning fish. Policy derived from this kind of thinking boggles the mind.

On a smaller scale of genetic bottlenecking, consider a small stream where salmon have been spawning for centuries. Let us say there were 50 redds in this stream. At some hypothetical moment, a mud slide further upriver washed out 49 of the Redds. Now the genetic pool for the entire population in the stream is limited to the offspring from a single Redd. How often has this happened in our rivers? Each time a major loss takes place, the diversity of the gene pool is reduced. That does not mean these fish will not survive. Like the buffalo, they still have a basic combination of genes that have kept them resilient over the years. However, the diversity of the gene pool within that watershed is reduced.

Gene Function and Diversity

The genes within any species are responsible for the development of specific proteins that have specific functions within the body. But being able to identify a gene in DNA testing does not mean the function of that gene is always known. For example, when a geneticist looks at the genetic code within a fish, there are ways to examine the DNA and separate many of them into phenotypes or fractions of the DNA. If a difference is found between two fish, the value of that difference may be unknown. The test only identifies the difference, it does not provide their function. With improved methods for DNA testing, it is not uncommon to find differences between fish from various geographic locations or hatchery fish from natural origin fish, especially if they spawn in different areas of the same river or were out of basin stock originally.

It is a general theory that the greater the diversity of DNA genes, the more fit the individual to survive changes in their

Jim Pex Jr. with a fly caught Chinook.

School children volunteering at the Morgan Creek Hatchery.

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environment. The greatest diversity of genes occurs when both parents are not related to each other. This diversity can be diminished by artificial means of reproduction such as can occur in a hatchery depending on hatchery practices. Fresh brood stock from the same watershed is imperative to maximizing gene diversity.

Straying Fish

The gene pool for anadromous fish also benefits from fish that naturally stray from their home waters to other streams. This is common and the presumed standard used in fish management is about ten percent. The origin of this number is unknown and could vary from stream to stream. Among natural spawning populations, this process ensures the diversity of genes and may also help repopulate streams where the original fish were lost due to some incident, natural or man caused.

Another form of perceived straying is hatchery fish that spawn in a river. ODFW has a team of people who visit selected sites on our rivers at specific dates to count fish or fish carcasses regardless of river conditions. The fish counts are based on live fish or carcasses found in a few miles of river where there is access. Those fish missing an adipose fin are considered hatchery even though not all the hatchery fish may have been fin clipped. These counts are problematic in general and useless when the river is high and off color at the time of the survey. This is the number used in the term pHOS or percent of hatchery fish naturally spawning in the river. These numbers may or may not be representative of the true population or percent hatchery fish spawning in the river. Studies have shown that hatchery salmon will normally spawn near the hatchery if they cannot get in the hatchery. However, it is common to use percentage numbers that suggest a total mix of natural spawners and hatchery spawners. A direct misrepresentation of what may be happening in the river. As an example, data from Elk River with high pHOS were primarily drought years and hatchery fish may have had difficulty getting in the hatchery. A manmade problem.

Steelhead counts are more difficult because they do not die but return to the sea after spawning. They may enter a river, spawn in one night and return to saltwater without being seen. In addition, the steelhead redds are visually no different from coho redds. It is not uncommon for coho to be in the river at the same time as the returning steelhead. This complicates the counts if the fish are not on the redds at the time of observation and the water is clear enough to see them. Again, observations are done at certain predetermined times at specific locations. There just are not enough staff to continually monitor Oregon's rivers and streams. The results of the surveys are often multiplied by some factor to reflect what might be considered the total number of fish returning. In my conversations with fisheries biologists, this method of data collection is half science, half speculation. Software programs assume that wild and hatchery fish are equally distributed and randomly spawning with each other. As we have seen, this is not true geographically and also larger males tend to spawn with multiple females. Formulas utilizing pHOS to determine reproductive success assume the following:

1.Hatchery and wild fish would have to have the same spatial distribution within the naturally spawning population.

2. Hatchery and wild fish would have to have the same temporal distribution within the naturally spawning population.

3. Hatchery and wild fish would have to have equal probability of successful natural mate selection.

4. Hatchery and wild fish would have to have equal probability of successful mating.

All four have considerable variability from watershed to watershed.

Methods of Hatchery Reproduction

Discussions with retired fisheries biologists reveal some hatchery production in the past has been done as expediently as possible to meet the available human resources at the time. Whatever returned up the fish ladder to the holding pond was used. When this process was repeated year after year, it matters. There will be a high likelihood for matching of relatives. As mentioned before, the diversity of the gene pool is reduced, and reduced relative fitness may be a possibility. In a NOAA report, the following definition was used for relative fitness:

"*The breeding success or survival of one group measured as a proportion of another group. In this report, relative fitness of hatchery fish = (hatchery fish survival / natural fish survival) × 100, the result of which is expressed as a percent.*"

In another discussion with a retired ODFW biologist I asked him how many different methods of hatchery spawning he had seen in his career. He said what was done was up to the local field biologist and historically there was no known standard procedure. It could vary from placing all the eggs in a bucket and using one male for fertilization or doing products from five fish in a bucket at a time or just about any combination you could think of that was expedient. I digress for a moment, but I have never seen a research paper about hatchery reproductive success that mentioned the method of hatchery reproduction. In addition, you might ask yourself, what was the percent of hatchery fish fin clipped? What if it was only 50%? The historic numbers used today are based on the presence or absence of an adipose fin. What is truth?

There are repercussions for poor hatchery techniques just as with other species. Examples can also be seen in mammals including humans. For example, some human populations either through religion or geographic location may develop abnormalities over time not common to other areas where genetically mixed populations exist. Some problems are referred to as inborn errors of metabolism. With these people, inbreeding causes abnormal development of internal proteins and rare diseases develop. Common conditions of animals subjected to inbreeding include reduced fertility, fewer eggs, physical defects, lower birth weight, slower growth and immune deficiencies.

A paper published by the Washington Department of F&W in 2006 stated:

"Mean egg weight (SD) of the hatchery fish was 0.23 (0.03) g and 0.23 (0.04) g for the naturally produced fish. No difference was found between the mean fecundity (P = 0.07) and egg weight (P = 0.33) of hatchery and naturally produced age-4 fish in 2005."

They also found the adult hatchery and native origin fish to be comparable in size. Inbreeding does not present itself in these characteristics in this study based on their hatchery practices. Emphasis on their hatchery practices.

To improve diversity at the Morgan Creek Hatchery in Coos County, we take this approach. About a cup of eggs or sperm is taken from each fish used for reproduction. Pairing is one to one and the DNA from every fish contributes to the next generation. In addition, all eggs and sperm from brood stock of the natural spawning fish population is interspersed into the program. It is not a perfect system, but it improves gene diversity. Greater gene diversity suggests better reproductive fitness although there is no measure to demonstrate what is a scientific norm.

Genetics and Return Time

It is interesting that one of the first gene related changes seen in salmon and steelhead raised in hatcheries is a shortened timeline for their return to spawn. In coastal rivers, natural spawning fall Chinook used to return anytime from August through December. Hatcheries tend to take the first fish that return and stop taking eggs when they have reached a predetermined quota. The late returning fish are often excluded, and the result is a fishing season targeting hatchery fish primarily in the early fall. In some areas, by late fall, there are fewer hatchery fish to catch. If eggs had been used from the late returning fish too, we could potentially have had an active hatchery related fishing season that could be extended for several months. This is an example of genetic change that may be artificially created by hatchery management. On the reproductive fitness side, these fish may return too early for optimum river conditions and demonstrate poor survival compared to NO fish that return later when river conditions are more favorable.

Epigenetics

Some recent papers suggest genetic changes take place while juvenile fish are within the hatchery(F1). That the changes could be permanent and can be passed on to the first generation (F2) of offspring and reduce reproductive fitness if they spawn in the river. But the effects disappear when this new generation returns to spawn producing the third generation of fish (F3). The belief is that this phenomenon falls within the field of epigenetics.

Wikipedia defines Epigenetics, in part, as follows:

"In biology, epigenetics is the study of heritable phenotype changes that do not involve alterations in the DNA sequence. [1] Epigenetics most often involves changes that affect gene activity and expression.

In short, nothing changes with the genetic makeup of the species, it is a matter of activation or inactivation of existing genes.

The theory suggests juvenile fish in a hatchery adapt to the hatchery environment by control of how and which already existing genes are activated or fail to activate. Researchers in British Columbia found epigenetic differences in hatchery smolts v natural origin smolts but were quick to point out it is unknown if these differences have any relationship to survival. The resulting function of these changes was unknown.

The term used for this reported change is "domestication." In essence, the grandparents were raised in a hatchery, but the third generations are now natural origin (NO) spawners. The problem went away. What is common to "domestication" papers as stated before, there is no mention of hatchery reproductive methods, in hatchery conditions prior to release, river conditions at time of smolt release or any predation issues at the time of release. Yet less reproductive success is implicated.

One must ask the question, if six weeks in a hatchery pond caused a gene activation leading to domestication when these fish become adults and reach the natural spawning grounds, why isn't the apparent activation reversed and the fish revert back to what they have done for a millennium in the natural environment? Why does it take two generations if this is activation or suppression of existing genes in response to the environment?

If we look back, say one hundred thousand years, there have been numerous changes to the environment including ice ages. In theory, anadromous fish that had the ability to adapt survived in part by activating or deactivating existing genes. Domestication is often defined as generating a population of fish less fit to survive in the wild compared to their natural spawning counterparts. In some instances that could make sense, especially if you release the unprepared hatchery fish all at once lower in the river, directly into an environment ripe with predators such as cormorants and seals. Fewer adults may return years later but this has nothing to do with genetics. It has everything to do with hatchery smolt introduction into a hostile environment without time to develop defensive strategies.

Not all researchers see the domestication issue related to anadromous fish the same way. The following is an excerpt from a recent publication focused on coho salmon where hatchery stock smolts were planted in upper tributaries to repopulate the stream.

"In spite of negative domestication effects that may have accumulated within this coho stock, a portion of the reintroduced hatchery smolts not only returned as mature adults to these rivers, but they also successfully spawned, and their natural-origin progeny are returning in increasing numbers and produced a second and now third generation. There have been dramatic increases in annual escapement to each of the subbasins. There have also been dramatic increases in annual redd counts, as well as expansion in the range where spawning is occurring. It would appear that any accumulated domestication effects within this out-of-basin hatchery stock is being reduced by the effects of broodstock management and by natural selective forces, creating populations of increasing natural productivity."

In addition, a fisheries resource management group with the Nez Perce Tribe published a paper in Molecular Ecology and made the following statements in the abstract:

"*Results show a demographic boost to the population from supplementation. On average, fish taken into the hatchery produced 4.7 times more adult offspring, and 1.3 times more adult grand-offspring than naturally reproducing fish. Of the wild and hatchery fish that successfully reproduced, we found no significant differences in RS between any comparisons. (RS is reproductive success.)*

They conclude the following:

"*We conclude that fish chosen for hatchery rearing did not have a detectable negative impact on the fitness of wild fish by mating with them for a single generation. Results suggest that supplementation following similar management practices (e.g. 100% local, wild-origin brood stock) can successfully boost population size with minimal impacts on the fitness of salmon in the wild."*

These conclusions were based on field data, not in lab testing or software models. Perhaps there is something to be learned from their hatchery practices.

A great fall day on the ocean.

Local Fish Politics

With over 100 years of hatchery influence, the current politics is to ignore any positive impact of hatchery fish. Ironic, considering in past years some hatcheries may have fin clipped as few as 30% of the smolts. The true definition of a Natural Origin (NO) fish is not a unique gene pool or pedigree as many people think, but the presence of an adipose fin. Still, some people believe that hatchery fish are inferior anyway and have pushed that concept in the media. If so, just how inferior are they? What are the measurables? What is the quality difference between fish from hatcheries that use brood stock to those that do not? Are some hatcheries producing a better fish product that others? Some research says they are. Hatchery fish will return to the hatchery unless there are factors preventing the return. In that case, an increased number tend to spawn in the main river near the hatchery. A location often not optimal for survival of the offspring. As these returning fish mature to a spawning state, time runs out and they do what nature intended them to do, spawn somewhere near their origin.

Again, in the paper published by the Washington Department of F&W in 2006 stated the following:

"Pearsons et al. (2004) reported that 73% of the estimated number of precocious males in the upper Yakima Bain were found in most downstream reaches of the potential spawning habitat. The low abundance of hatchery precocious fish on the spawning

grounds in the Wenatchee Basin suggests that the most hatchery precocious fish do not successfully migrate to the tributary spawning areas, or they die, as observed in the upper Yakima Basin."

In a study of Wenatchee spring Chinook, the following paragraph was in the introduction:

"The reproductive success of hatchery origin fish may be lower than natural origin fish if hatchery origin fish spawn in suboptimal location. For example, hatchery fish may spawn in unproductive tributaries, portions of unproductive tributaries, or at microhabitats that are suboptimal. If acclimation ponds are located in a suboptimal spawning location and the fish home back to these locations, then the reproductive success of hatchery origin fish may be compromised. In short, reproductive success of hatchery origin fish could be compromised even if they are genetically and behaviorally identical to the natural origin fish."

This suggests a human management or weather factor, not a fish genetic factor. Where hatchery fish are released is important. Where hatcheries are located matters. If hatchery fish spawn in the main river because they cannot get into the hatchery due to low water conditions, it matters. The next highwater event will likely eliminate most of these in river hatchery fish eggs or offspring giving the appearance of reduced RS. The following study made observations on carcass location not seen in other studies.

"Williamson et al. (2010) found that hatchery- origin Chinook tended to be younger and to return to lower areas of the watershed than natural- origin Chinook. However, the hatchery fish were released lower in the Wenatchee River than where the natural fish were spawning. Other than differences in age structure, carcass recovery location was the only measured trait that differed notably between hatchery and natural- origin fish. Carcass recovery location also had a significant effect on fitness, such that fish that were recovered higher in the watershed had higher average fitness than those that were recovered lower in the watersheds."

This makes sense but may have more to do with location than genetics.

The political current is now toward less hatchery fish and less fishing opportunity, with natural origin fish taking precedence over the needs of folks paying the bills. Studies have repeatedly shown the removal of hatchery fish in a river did not improve the numbers of NO fish. Reproductive or relative success of hatchery fish is the measure in today's fish management. Whatever value is used, is highly variable depending on who's research you read. Relative fitness is not just genetics, there are many non-genetic factors that may contribute to the relative fitness of a given hatchery stock. Some are due to human management and can be improved.

Fly fishing for Chinook on the south coast. Fish on!

All comparative research requires the control of variables. The comparison of hatchery fish to natural origin fish in different locations or environments makes assigning a specific value to relative fitness highly variable and difficult. With multiple hatchery methods of reproduction and release in less favorable locations, it would be unreasonable to see a direct 1:1 comparison to natural origin fish in the same watershed. If natural origin fish spawn in favorable habitat and hatchery fish are released in less favorable habitat, why would one expect an equivalent number of hatchery fish to return? As expected, calculations for relative fitness of hatchery fish are less. The physical factors are usually ignored, and a genetic component is often implied.

In all fields of science, if there are opposing conclusions to the same questions, the question is not answered. What went on in one study in one river or hatchery may not necessarily apply to all rivers and all hatcheries. What is apparent is what may be perceived as genetic or pedigree harm by hatchery fish may have as much to do with how some hatchery fish are raised or the location of in-river spawning. To date, any genetic difference between hatchery fish and NO fish found within the same watershed is identified as the culprit to a less suitable hatchery fish. Over time the manmade assault on anadromous fishes continues to increase with human population expansion, habitat loss and overfishing. If hatcheries are discontinued, the numbers of anadromous fish will fall even further reducing or eliminating cultural, commercial and sportfishing take. When I am at a hatchery and watch the senseless killing of winter steelhead because the egg quota has already been reached, there is something really wrong with our current hatchery practices. Perhaps money spent on the Oregon Hatchery Research Center could be spent researching all aspects of hatchery methodology and level the playing field between these fish and their cousins, from the same watershed. Hatchery fish have value for the consumers, not just a backup for NO fish. Simply finding a genetic (phenotypic) difference and ignoring the non-genetic issues is an inadequate approach to restoring our runs to maximum sustainable levels in today's environment. Contrary to a recent document published by ODFW, I am not looking for the "opportunity" to fish. I am looking for a river full of fish with the chance to fire up the barbeque. That is not an unreasonable expectation considering what I pay the state to fish.

From what I have read, research funded by the Columbia Intertribal Commission is promising for better hatcheries and hatchery fish. Wouldn't it be ironic if it were the native Americans of our community that restored our anadromous fish back to historic levels. After all, they were the first salmon people.