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Measuring Long-Term Changes in the Fall Chinook Population in Elk River
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Measuring Long-Term Changes in the Fall Chinook Population in Elk River1

At this meeting and several others in recent years, we have heard some fairly complicated papers dealing with genetics. What I would like to do now is to explore the following question in what I hope will be a simple and general way. If Elk River Hatchery, built in 1968, has been successful to date with survival rates averaging 3 to 5% and with good contributions to the sport and commercial fisheries, does it necessarily follow that the hatchery program will be successful into the future?

A while ago a commercial fisherman told me that a fish is a fish is a fish. He said that all we had to do at Elk River Hatchery was to just keep producing chinook salmon because it didn't matter to him if the salmon he caught were wild or hatchery; it didn't matter to him if they were male or female; and it didn't matter to him about any of their biological characteristics, because he got $2.50/lb in the troll fishery, and as far as he was concerned, the name of the game was dollars times pounds. The viewpoint of most sport fishermen is also that a fish is a fish is a fish.

I can appreciate their simplified view of the problem. They will be happy as long as our program is successful and we produce lots of salmon for them to catch. But I don't agree that a fish is a fish is a fish! And I don't believe they would agree either if they spent more time thinking about the problem.

For example, the commercial fisherman would obviously be better off if each fish he caught was bigger. He would be worse off if the timing of the run was shorter and the fish were available to him off the mouth of the river for only a brief period. Likewise, the sport fisherman is now happy with lots of fish, but he would be quite unhappy if the jack component of the population suddenly disappeared because jacks are the mainstay of the sport fishery. On the other hand, he would be most pleased if the run extended over a longer period of time and bright fish entered the river long before they were ready to spawn.

These are examples of just a few characters that do matter to the fishermen. We could list many others. But probably the most important characters to them and to us are the ones that lead to biological fitness in the population and assure that the population will be successful generation after generation.

There is a vocal group of sport fishermen that claim they can detect the difference between wild and hatchery fish (other than by a fin clip), and they want more wild fish. I, too, favor more wild fish but not for their reasons. I don't think wild salmon in Elk River are better quality fish or better fighters than our hatchery fish, but they are biologically fit. They have undergone extensive natural selection and possess the biological variability that is necessary to survive.

Many of the characters that lead to fitness or survival are at least partly under our control in a hatchery program. Some characters we openly select for in our egg-taking operations. Others are selected inadvertently along with associated characters. And still others are selected unconsciously as the fish we rear adapt to our artificial systems by how well
they survive to contribute to the next generation. Those same characters that lead to survival in the population can just as easily be left out in our hatchery operations.

Now to start with, if you buy any of the genetic concepts involved in a hatchery operation, and that we can by our procedures affect what those fish look like or what they do, then you have probably already changed your definition of "hatchery production". Hatchery production should no longer be considered simply a game of numbers where the magic "million" or some multiple thereof is the common denominator. The measure of success of a hatchery program should not be in pounds or numbers of fish released. Nor is the distinction between an experimental release and a production release one of numbers. Nature does not have any production releases. She has only experiment after experiment to test the environment. Some of nature's experiments are big--and some are small.

Natural populations do not develop a system and then stick with it year after year. Natural populations are dynamic, variable, and responsive to the environment. Our hatchery systems on the other hand often tend to be traditional, static, and sometimes we seem to go to great pains to reduce variability so we can reduce our work loads and fit our schedules. We like our fish spawned on one day, ponded on one day, and released on one day. That may be an overstatement, but just how important is variability and how far can we abbreviate or deviate and expect to have continued results?

When we talk about hatchery production, we need to be thinking in terms of survival and contribution. We need to be thinking about meeting the specific needs of the various fisheries we serve. And most importantly, we need to be thinking about environmental fluctuations and assuring continued biological
variability in our populations to correspond to those environmental fluctuations. Only in that way can we perpetuate our hatchery programs. It then follows that we must stop considering that an egg is an egg is an egg. A few eggs from genetically well-chosen (but not necessarily selected) matings reared under a biologically sound program probably means much more than a full hatchery.

We hear all kinds of reports about a great success story in one hatchery in one year or in another hatchery in another year. Sometimes these same hatcheries have failures. We look for their "secret of success", but when they fail, we all shrug our shoulders and cite a bad water year, ocean conditions, an unknown disease, or whatever. But in most cases we don't really know why we either succeed or fail. I think this points strongly to problems of biological variability and shows the real value of our research work at Elk River.

Elk River is one of the few places where we have started a hatchery program from a wild stock and are monitoring in detail some of the changes that occur through time as we convert the population to a cultured stock. By keeping reasonably accurate records on the background of fish used in the program and their successes and failures, we may be able to demonstrate biological reasons if in the future survival rates at Elk River drop or begin to fluctuate dramatically from year to year. There are a few areas where we may have already deviated substantially from variability in the natural population and some changes in the hatchery population may be following.

I hope I will give you some ideas to think about in your own programs, but you will want to be careful about generalizing from Elk River to other rivers and especially other species. Biological fitness manifests itself in many different adapted characters. A particular way of solving a problem in
one population or a favored or selected character in one river or one species may not be the same in another. Each population is a separate entity and so is each hatchery operation. But although the specific characters change, the biological concepts are the same.

As a jumping-off point, I want you to consider the differences between a wild and a hatchery population. Mother Nature takes a lot and makes a few good ones, but in our hatchery programs we take a few and try to make a lot. Natural populations expose as much biological variability as possible to the environment in a grand experiment and the adapted ones survive. The environment may change from year to year, but the natural population usually has a broad enough spectrum of genetic types to respond and survive with "reasonable stability" in run size from year to year.

Consider this normal population (Fig. 1). Most biological populations tend to be distributed in this manner for a whole series of characters. So pick any character you wish to think about on the lower axis. For example, it could be egg size, fecundity, growth rate, or time of spawning. Over many years of time and a range of environmental influence, individuals tend to be favored at the midpoint of this distribution. Individuals cluster about the mean with the general variability shown. Through the years environmental shifts may occur and fish to the right or left of the mean of the population are better suited and are able to respond to those environmental conditions. The mean of the population may then temporarily shift to the right or left.

Now consider this population (Fig. 2) which we will say represents time of spawning in a natural population of salmon. Spawning starts early, builds to a peak, and then declines. Then let's say we build a hatchery on that river and start to take eggs from natural spawners. In our hatchery
Fig. 1. Most biological characteristics of a fish population follow a normal distribution. Mean = $\bar{x}$; standard deviation = $\pm$ S.D.; and the range of values = Max. and Min.
Fig. 2. A generalized distribution of spawning time for a population of salmon.
programs, we are notorious for being anxious to get our egg quota into the hatchery, so we start taking eggs when the first fish begin to spawn. We continue to take eggs until our egg quota is satisfied (shaded area). What has happened? We have drastically reduced variability for spawning time in the hatchery population. Instead of spawning from A to C, the hatchery population spawns from A to B. There is nothing wrong with an abbreviated spawning time as long as water conditions are good during the period when these hypothetical hatchery fish return to spawn. But if there is a drought and the first rains come much later, it will be too bad for the hatchery population. We can further generalize this situation to say that populations with low variability in relation to large environmental fluctuations tend to be boom or bust. As long as environmental conditions coincide with the genetics of the fish present, then they do great, but if they don't coincide, then the population has low survival.

Let's look at time of spawning for fall chinook salmon naturally spawning in Elk River (Fig. 3). The population begins spawning in mid November, builds to a peak in late December to early January, and subsequently declines. Mean date of spawning is December 28.

Now consider what we have done in our egg-taking operation for the rearing program at Elk River Hatchery (Fig. 4). In the first three broods, we took our eggs from natural spawners captured with dip nets in Anvil and Rock creeks. The fish were relatively hard to catch and the egg take was a slow operation. But our egg take followed quite closely the time of natural spawning, as it did even in 1971 when the first hatchery females came back at age 3. However, by 1972, success had fully arrived and a lot of hatchery females were available at the hatchery and our egg take was abbreviated and earlier than in previous years. Some fish were spawned later, but these
Fig. 4. Date of egg takes at Elk River Hatchery, 1968 to 1975.
NS = natural spawners.
were shipped to other areas. In 1973 the trend continued, even though we had some late experimental eggs. That is indicative of what I think could have been a very dangerous trend. However, our policy is now that we take eggs for the Elk River program throughout the run and the picture shown for 1975 is hopefully indicative of what will be happening in the future.

Now let's consider some other ways we may have possibly deviated from the natural variability in our hatchery program. In Table 1 are shown population estimates for wild jacks, wild adults, hatchery jacks, and hatchery adults in a series of spawning years. Note that the wild population tends to have a large jack component. In some years the number of jacks equals or exceeds the adult population. Jacks are important contributors to the gene pool in the wild spawning population in Elk River. However, when the hatchery operation started in 1968, we left out this major component of variability and used only adult males for spawning unless we were desperate. Hatchery jacks were abundant for the first four years of hatchery returns, but then they drastically declined in 1974 and 1975. On the basis of percent return from release, the jacks in 1974 and 1975 only returned at 0.10% and 0.16% compared to 1.19%, 1.97%, 0.77%, and 0.62% over the previous 4 years.

In 1976 a large number of hatchery jacks again returned to the river, but they came almost exclusively from an age-3 $\sigma \times$ age-3 $\varphi$ cross, whereas the return from a similar cross of age-5 $\sigma \times$ age-5 $\varphi$ produced almost no jacks.

To help assure that drastic fluctuations like this don't continue at Elk River Hatchery, we plan to include more variability in the males we use for spawning, including jacks. The males will be equally represented in a sperm pool by three groups: jacks, age 3, and ages 4 and 5, and the total number of males will be equal to the number of females spawned.
Table 1. Estimated number of wild and hatchery fall chinook salmon entering Elk River, 1970 to 1976.

<table>
<thead>
<tr>
<th>Spawning year</th>
<th>Wild Jacks</th>
<th>Adults</th>
<th>Hatchery Jacks</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-71</td>
<td>2,457</td>
<td>3,355</td>
<td>3,826</td>
<td>0</td>
</tr>
<tr>
<td>1971-72</td>
<td>1,040</td>
<td>1,421</td>
<td>2,121</td>
<td>1,929</td>
</tr>
<tr>
<td>1972-73</td>
<td>747</td>
<td>1,392</td>
<td>5,240</td>
<td>5,154</td>
</tr>
<tr>
<td>1973-74</td>
<td>1,059</td>
<td>2,029</td>
<td>3,405</td>
<td>5,930</td>
</tr>
<tr>
<td>1974-75</td>
<td>1,150</td>
<td>2,110</td>
<td>432</td>
<td>5,790</td>
</tr>
<tr>
<td>1975-76</td>
<td>1,750</td>
<td>1,714</td>
<td>495</td>
<td>9,237</td>
</tr>
<tr>
<td>1976-77</td>
<td>2,800</td>
<td>1,475</td>
<td>3,975</td>
<td>1,278</td>
</tr>
</tbody>
</table>

We no doubt have done other things different from nature and reduced variability when we started the hatchery operation. A few items we know about are: 1) in addition to not using jacks, the males we did use were often used repeatedly so only a relatively small contribution of different genetic material came from males; 2) only a relatively small number of females was used in the hatchery compared to what happens in the wild population; 3) spawners were captured from only 2 tributary streams rather than throughout the river including all tributaries and the main river; 4) spawners were mainly from those spawning between freshets when they could be easily captured; and 5) fish that might not have been successful at choosing a mate or completing spawning, or those selecting an inferior redd site, or those with characteristics such as very large or very small eggs and a reduced chance of survival in the gravel were chosen along with others.

In the process of artificial spawning, we likely carried some genetic material into the hatchery program that normally is selected out in nature. In Fig. 5 is shown the general differences between survival rates of eggs and alevins in the gravel and in the hatchery. Much of the high mortality in the gravel may be due to random environmental problems, but some is also due to lack of genetic fitness. This concept is somewhat confusing.
Fig. 5. Generalized survival rates of eggs and alevins in natural reds in Elk River and in hatchery incubators.
What I am saying is that the selective pressures in nature and in the hatchery are quite different. We have the potential to change the hatchery population not only by what genes we exclude in our egg take, but also by what genes we carry on welfare in the hatchery.

One aspect of variability that has changed in the hatchery program through the years is the proportion of wild females used (Fig. 6). When the hatchery operation was started in 1968, we captured fish from the spawning tributaries with dip nets, and since there were no hatchery fish in the river, we used 100% wild fish with all the variability those particular individuals had to offer. This was also the case in 1969 and 1970. In 1971 the first females returned to the hatchery and they began entering the adult pond so that we did not need to chase spawners in the creeks as much to satisfy our egg needs. The proportion of wild fish dropped considerably. Since 1971 our eggs could quite easily be obtained from hatchery fish returning to the hatchery. Less than 10% of the spawners in the last 4 years have been from wild fish. We may decide in the future that it would be desirable to reinfuse wild fish occasionally into the program to help bring back variability.

Another area where some changes from the natural population may be occurring is in the age of females being spawned (Fig. 7). Since we were capturing spawners from the creeks during the first three years of the hatchery operation, the age composition of females followed the natural population quite closely. Age-4 females predominated, followed by age-5 and age-3, respectively. In the natural population age-3 fish are only about 20% females and the remaining 80% are males. However, in 1971 when the first hatchery females returned, many entered the adult pond, and because of their availability, were heavily used in the egg taking. The age distribution
Fig. 7. Age distribution of females used in the egg-taking operation at Elk River Hatchery, 1968 to 1975.
was substantially shifted to age-3. In 1972 and 1973, the age distribution was strong to age-4 again, but in 1974 the strong selection for age-3 fish in 1971 produced a large return of age-3 fish in 1974 which we also used. Although we have been capitalizing on this line of age-3 fish in some selective breeding, in the long run we will likely want to assure a more uniform distribution of ages of spawners in the bulk of our program.

In conclusion, I have shown you some deviations from some of the variability we knew to exist in the natural population in Elk River and have hopefully set you to thinking about these kinds of problems. Some of the identified areas were only hints to changes in the population that we have taken steps to correct before they got out of hand. How many other characters we have overlooked is unknown. How important these deviations might be in the long run is too early to tell. Elk River Hatchery is still a highly successful program, but we will continue to monitor some of these and other characters for additional generations. I believe our best strategy at this hatchery and possibly most hatcheries is to maintain as much biological variability as possible in the program to assure reasonable stability from year to year. At the same time, we can cautiously test genetic selection for desirable traits in part of the production to improve survival and contribution to the fisheries.