Background of the Genetics Policy of the Alaska Department of Fish and Game

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Number 95
Alaska Department of Fish and Game Division of Fisheries Rehabilitation, Enhancement and Development

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March 1989

INTRODUCTION

The salmon industry of Alaska is dependent on production of salmon from wild populations. In the early 1970s, a system of public and private nonprofit hatcheries was created for the rehabilitation and enhancement of salmon populations. This came about largely because of several years of very low returns of salmon to many areas of Alaska. This depression of wild stocks was coupled with increases in knowledge of incubation and rearing requirements of salmon. However, the importance of the wild stocks of salmon to the state economy was recognized as paramount. It was also understood that the development and operation of a hatchery system could, if not done with care, have a detrimental impact on wild salmon populations. There has never been any intent to replace wild populations with hatchery fish. The intention is to augment wild production and, perhaps, even reduce fishing pressure on wild systems. A provisional genetic policy was developed in 1975 by the Department of Fish and Game (ADF&G) to protect wild stocks from enhancement activities. It has been revised twice (1978 and 1985). The revisions have extended the policy by developing guidelines that provide for the application of genetic principles to the development and management of brood-stock for the hatchery system. The revisions also clarify the rationale for the policy guidelines, and reduce ambiguity in the policy. Protection of wild stocks remains the principal objective of the genetic policy.

Our goal is to discuss the genetic policy and the genetic principles on which it is based. We also will discuss some of the problems encountered in trying to implement the policy.

Finally, we will review the policy in an attempt to determine if, in its present form, it achieves the objectives for which it was developed.

PROBLEM

Genetic impacts to wild, indigenous fish stocks becomes a possibility when man decides to (a) transport fish from one locale and release them in another, and (b) when man decides to create by artificial means (hatcheries) fish to supplant those produced by nature. It is important to recognize that to conduct these activities does not automatically mean that genetic impact to wild stocks will follow. The attention man gives to preventing impact will determine whether any impact ensues. While not a topic for discussion here, it should be mentioned that the most clearly demonstrable genetic impact to wild salmon has been produced by commercial harvest.

What are the potential genetic hazards to wild fish populations brought by transport associated with enhancement? There are two. The first hazard is with the effects of gene flow between fish stocks. Gene flow occurs naturally between local stocks of the same species, but our concern is that fish released either at a hatchery or off-station may stray and interbreed with local wild stocks. If these stray fish are poorly adapted to the environment, the fitness of the local stocks potentially can be impacted. It is presumed that wild stocks have been adapted by natural selection to their native environment. Interbreeding with hatchery fish or transplanted wild fish, because these have adapted to a different environment, could reduce the fitness of the local stock. Although we are primarily interested in protection of wild fish stocks, the same dangers exist for hatchery brood stocks.

The second area of concern is with maintaining adequate genetic diversity both within and between fish populations. There are two components to the diversity in a species. There is the variation within each stock and also the diversity among stocks. Both of these components are important to the well-being of the species.

GENETIC CONCERNS

The science of Population Genetics has been developed over the past 70 years. It is true that there is little, if any, direct information on the genetic impacts of salmon enhancement on wild salmon stocks. However, there is a large body of theoretical and experimental work; the experimental work has been based on a wide variety of plants and animals other than fish. We have applied that body of knowledge to the development of the genetic policy.

What We Know

Genetic Variability and Fitness:

Our approach to policy development has been based on principles of population genetics theory. Population genetics deals with diversity, phenotypic diversity but, especially, with that portion of diversity that is caused by differences in genotype among individuals. A great deal of effort in population genetics is expended in determining the amount of genetic variation that exists both within and between natural populations. Genetic variability is the raw material which allows a population to adapt to its environment. Genetic variation, in addition, seems to increase the physiological stability of individuals and populations. In addition to genetic variability, a central factor in salmon population genetics is population structure. Salmon stocks home with remarkable precision to their "home" stream to spawn. Behavioral barriers to gene flow result in a significant degree of genetic diversity among salmon stocks. The amount of diversity is dependent on a number of factors, such as time since stocks separated and amount of gene flow between stocks. The amount of gene flow may be related to distance between stocks, or other impediments to migration.

Fitness can be defined as the probability that an individual will survive from conception to reproduction. However, we are primarily interested in the average fitness of the population or stock. It is very difficult to measure the total fitness of an individual because of the complexity of the trait. Anything that can increase or decrease the chance of an individual's survival to maturity affects the fitness of that individual and, therefore, the average fitness of the population to which it belongs. Any loss of genetic variation results in a loss of fitness, but any gain in genetic variation may or may not improve fitness.

What We Think We Know

It follows from what we know about population genetics theory that wild stocks must be approximately in genetic equilibrium. Being in genetic equilibrium means that though the population is constantly subject to natural selection tending to increase fitness, the gene frequencies remain relatively stable and fitness does not improve. The reason this is the case is that additive genetic variance (that portion of genetic variance that will respond to selection) will, over time, have been removed from the population by natural selection. (This has been called the "Red Queen" hypothesis after the character in Alice In Wonderland who said it was necessary to run as fast as they could to stay where they were.) Therefore, a wild stock at any particular location is assumed to be close to maximum fitness and, therefore, the stock best adapted for that location.
We assume also that transplanted salmon will not home as accurately to the new location, at least initially, as native salmon. Homing of some transplanted salmon has improved rapidly over the first few generations at a new location. This lends support to our assumption.

Finally, genetic distance and geographic distance are assumed to be correlated. Although salmon home with a remarkable degree of accuracy, there is some straying. Chances are that they stray into nearby streams with greater regularity than into more distant streams. It is not unreasonable, therefore, to assume that gene flow between neighboring stocks would result in genetic similarity. Having made that assumption, we have to recognize that there will be exceptions to this general rule. Life history characteristics, environmental features, and geological formations can effectively block gene flow between stocks that are geographically close.

Given these assumptions, we might also consider factors that would enter into an objective consideration of any proposed enhancement project. What is the environment to which salmon adapt? We should recognize that the environment of a salmon population is extremely complex. First, their environment encompasses both freshwater and marine habitats. Both environments vary spatially as well as temporally. In addition, it seems clear that salmon populations are characterized by a great deal of plasticity. Most salmon stocks are able to physiologically adapt to a wide variety of environmental conditions. Further, much mortality in salmon populations is due to pure chance or phenotypic difference rather than genetic selection. "Much differential survival and fertility is purely accidental - an animal may survive because it happens to be in the right place at the right time. This is especially true of organisms that produce a great excess of progeny of which only a few survive to maturity" (Crow and Kimura, An Introduction to Population Genetic Theory, 1970. Harper and Row, New York). Many of the assumptions on which we base our policy decisions are tied to the notion that the genetic composition of indigenous wild salmon is determined primarily by selection. The value of these assumptions is not necessarily negated by the understanding that many differences between stocks have arisen by chance, and environment can perpetuate phenotypic differences without the populations undergoing genetic change. Our basic assumptions represent the most conservative approach to policy; however, we must recognize that these unknowns exist.

SOLUTION

The genetic policy is the solution to the problem of development of a salmon enhancement program while protecting wild salmon populations. As stated earlier, the genetic policy was developed in 1975 to protect wild stocks from possible detrimental effects of artificial propagation and management practices. However, since public and private nonprofit hatcheries have come on-line and proven successful, additional guidelines have been added to protect hatchery and enhanced stocks. The policy was reviewed and revised in 1978, and again in 1985. The purpose of the genetic policy is still to protect wild stocks. The following describes pertinent genetic considerations and how these have influenced the development of the genetic policy.

From the beginning of enhancement efforts, there has been a recognized need for controls on the movement of salmon stocks. The Fish Transport Permit (FTP) was developed to provide control of fish transport. In order for anyone to transport, possess, export from the state, or release fish into the waters of the state, they must hold an FTP issued by the Commissioner of the Department of Fish and Game. Each FTP is reviewed and commented on by selected staff of the department.

Control of fish transport is the only method available for limiting gene flow into fish stocks that need to be protected. Indiscriminate movement of stocks can result in decreased genetic diversity among stocks. Development of criteria for the genetic review of FTP applications has been a problem since the permit was established. Specific knowledge of salmon population genetics and the genetic impacts of salmon enhancement on wild stocks is limited. Consequently, the genetic policy is based more on information from agricultural genetics and population genetics of other species than on knowledge of our own salmon resources. The result is a policy containing guidelines that are rather flexible. We have tried to develop nonambiguous criteria for judging fish transport permits. The policy suggests that because our knowledge is limited, we should apply the policy and presumably evaluate the FTPs conservatively. An attempt to act conservatively gives the appearance of being arbitrary and begs the comment that the policy is too ambiguous. Unfortunately, the present level of our knowledge forces us to be somewhat ambiguous in our guidelines. Conservative application of the genetic policy can occur only if we set somewhat arbitrary limits based on what we know about the genetics of populations.

APPLYING GENETIC POLICY

When stocks are moved, wild salmon are subjected to increased danger of genetic impact. Direct genetic impact requires first that gene flow occur from the transplanted stock to the indigenous wild stock and, second, requires that the fitness of the wild stock be reduced. Simple, starch gel electrophoresis of tissue proteins can often detect whether or not gene flow has occurred between two salmon stocks. But to prove genetic impact conclusively, it is necessary to demonstrate that the fitness of the indigenous wild stock has been reduced. Fitness is measured in terms of production of biomass by the stock, and any change in fitness must be a measure of that change in production ascribable only to gene substitution. Numerous environmental variables, both biotic and abiotic, also influence production by the stock, and so it borders on the impossible to measure any change in fitness (production) due to gene flow. Year-to-year variation in production due to this set of other variables masks any reduction in fitness that could be expected over a period of time. Hence, changes in fitness of salmon stocks due to interbreeding have never been measured. So it follows that direct genetic impact due to interbreeding has never been demonstrated in salmon.

The genetic policy has been developed to provide guidelines that will allow development of a hatchery/enhancement program while minimizing the potential for genetic impacts on wild stocks to an acceptable level. Stock interaction must allow for the long-term retention of natural communities under conditions that provide the potential for continuing evolution.

Significant Stocks

Salmon populations vary in size from intermittent runs, which may be maintained by straying, to runs of hundreds of thousands of fish. It seems reasonable that all salmon populations are not of equal importance. The effect of a salmon enhancement project depends to some degree on the relative value of the stock that might be impacted. The concept of significant stocks arose out of such considerations. Early versions of the policy (1975 and 1978) distinguished between introductions into systems with large indigenous stocks and into systems with few or no indigenous fish. The earlier policies made no attempt to set limits on population size but clearly had introduced the concept of significant stocks. The 1985 review and revision of the genetic policy was initiated because of a need to remove ambiguity and increase consistency in application of the policy. Members of the review committee were unable to define the term, "significant stock," but did develop an approach to the problem. The committee felt that, while the size of the population is important, "significance" must be defined not only by the magnitude of the run, but also in the context of local importance and utilization. The committee suggested as well that "Because local utilization is an important concern, a regional planning group such as the Salmon Enhancement Regional Planning Teams should consider what criteria will be used to determine significant stocks within a region and recommend such stock designations." At this time, these suggestions have not been implemented.

Genetic and Geographic Distance

The idea that genetic distance and geographic distance are correlated has also been used in developing and applying the genetic policy. We are led to this idea by two facts of salmon biology. Salmon stocks home to their own spawning grounds with some accuracy and adapt to that particular environment. This tends to cause some degree of genetic separation between stocks. However, there must be background levels of straying occurring between local salmon stocks. The fact that salmon species will repopulate barren streams is evidence that salmon stray; however, straying may also lead to reduced fitness of a recipient stock. Background levels of straying occur between neighboring, thus genetically similar, stocks. We become concerned when stocks that have been transported from distant locales stray because they are not genetically similar to local stocks. The chance that strays from one stock will interbreed with another is dependent on the distance between the two stocks. It would seem to follow that, other things being equal, two stocks that are separated by a short distance will be more alike genetically than two stocks that are separated by a greater distance. Every stock will have its own sphere of influence, circumscribed by the straying of its members. The influence of each stock will decrease with distance from its home stream.

Changes of location on the globe result in changes in the environment. That is, in general, environment also changes as a function of distance. This, coupled with the fact that natural selection works to adapt a stock to its environment, lends support to the assumption that genetic differences between stocks separated by a great distance are larger than genetic differences between neighboring stocks.

This relationship between genetic similarity and distance leads to two conclusions: First, local stocks transplanted to a site will have less genetic impact on indigenous populations because of their genetic similarity than stocks transplanted from a greater distance; and, second, stocks local to an area are best suited for transplant within the area or for development of a brood stock at a site within the area.

Salmon stocks have a genetic sphere of influence because of their life history characteristics. All stocks interact genetically with those around them. This concept has governed the way the genetic policy has been applied. It seems obvious as well that each hatchery or enhanced population will also have a genetic sphere of influence. The larger the production of the wild stock, hatchery stock, or enhanced stock, the greater its influence will be on surrounding stocks.

The effect of these genetic spheres of influence is that decisions made in the past seem bound to limit options for future projects. Consider what it means when all stocks influence and, in turn, are influenced by those around them. Transplanted stocks will impact the genetic composition of stocks adjacent to the release site. Because we assume that wild stocks are in approximate equilibrium, we must assume also that any genetic impact caused by a stock adapted to a different environment (a transplanted stock) will result in some loss of fitness to the indigenous wild stock. The reduction may not be critical; it is impossible to know. It is conceivable that the indigenous wild stock will derive some benefit from the introduction of genetic variation. The result would probably depend on the amount of gene flow that occurs. The amount of gene flow would depend, in turn, on ability to manage the enhanced stock so that straying of returns would be minimized. It would also depend on the degree of genetic difference between stocks and the reproductive success of the straying fish. This aspect of salmon population genetics is not understood. This problem reemphasizes the need to apply the genetic policy conservatively.

Transplants will modify to some degree the genetic composition of local stocks. When remote stocks are transplanted to areas with significant wild stocks, the wild stocks in this locale are changed to some degree genetically, and their status must be reconsidered. Future options may have been limited.

Multiple Use of Stocks

It is important to build stock diversity into the hatchery system. Salmon stocks differ in levels of disease resistance, temperature tolerance, acid tolerance, and in response to artificial selection. Stock diversity will tend to buffer the hatchery system against both natural and man-made disasters. Further, the ability to genetically improve hatchery brood stock performance in the future depends on the availability of genetic variability.

Such variability would be present in a hatchery system with a variety of diverse brood stocks.

There is an apparent conflict between the need for stock diversity in the hatchery system and the need to start up individual hatcheries as economically as possible. It is more economical in the short run to develop a hatchery brood stock from excess eggs of an existing brood stock than from a wild source. And, it is difficult to place a monetary value on the long-term value of stock diversity. The genetic policy limits to three the number of hatchery brood stocks that can be established from a single donor. It does not limit the number of release sites for terminal harvest. This limit on multiple use of stocks balances the need for short-term economy and the need to establish and maintain genetic diversity. It will limit the spread of a single stock.

CONCLUSION

Can the genetic policy in its present form be applied in a way that will achieve the objectives for which it was developed? The answer is yes. Although there is an inherent risk to wild stocks from the development and operation of a hatchery/enhancement program, this risk can be managed by reducing the genetic impact on wild stocks to an acceptable level. The need is not to avoid all genetic change, but to allow for the long-term retention of natural communities under conditions that would provide for continuing evolution. To achieve this goal, we have to apply the genetic policy conservatively. This means that if we know, for example, that genetic similarity decreases with distance and our decisions are not to be ambiguous, we must set arbitrary limits on distance a stock can be transported. An effective genetic policy must allow for implementing successful enhancement activities while protecting and maintaining healthy wild stocks.
There are only two primary genetic concerns in protecting wild stocks and implementing a successful enhancement program. The first concern is possible genetic impacts due to gene flow into wild or enhanced stocks. The second concern is the loss of genetic variation within or among stocks. We are obviously concerned with both wild and enhanced stocks. However, Alaska's valuable salmon industry is founded on production from wild stocks, and wild stocks are the source of genetic variation for development of enhanced stocks; therefore, our primary concern is wild stocks. Both gene flow and loss of genetic variation can potentially cause the reduction of total fitness in wild stocks and hatchery brood stocks. The genetic policy addresses these problems in its three main topic areas. The topics addressed are Stock Transport, Protection of Wild Stocks, and the Maintenance of Genetic Variance. The genetic policy addresses the genetic concerns adequately. The policy describes the genetic concerns and presents guidelines that protect wild stocks from impacts of enhancement activities, as well as protecting hatchery brood-stocks and enhanced stocks from the problems associated with loss of genetic variation.

The only problems with the policy are those of perception. It is our hope that this paper will serve to promote a better understanding of the policy. One important task remains to be accomplished: The Genetic Policy Review Committee (1985) outlined an approach to the problem of defining significant and unique wild stocks. Any designation of stocks as significant or nonsignificant will be arbitrary. However, some means of defining these terms is critical to the successful application of the genetic policy and must be found.