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STATE OF ALASKA

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DEPARTMENT OF FISH AND GAME

DIVISION OF FISHERIES REHABILITATION, ENHANCEMENT & DEVELOPMENT (FRED)

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RAPIFAX TRANSMITTAL SHEET

To: Molly McCammon

Date: 2-11-93

No. Pages 5 (following this page)

From: Jeff Hartman

Message: I will be sending out 300 pages of draft report and data to Jim Wilen today. I will be sending a draft of letter requesting data + final technical reviews from the researchers. Thanks.

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

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February 10, 1993

Ms. Molly McCammon
c/o Representative Carl Moses
Alaska State Legislature
State Capitol, Room 204
Juneau, AK 99801-1182

Dear Molly:

Following our February 8 conversation, I understand that I have permission from the Legislature to send some of the preliminary and final work products from the University of Alaska-Fairbanks' cost-benefit analysis to Dr. James Wilen at the University of California-Davis. I will ask Dr. Wilen not to distribute any copies he receives. He will be asked the following questions:

1. Are the work products analytically sound enough to be worth the effort of carrying out a technical review?

2. How long will it take to complete a quality review of the technical aspects of the cost-benefit analysis model and report, demand model, cost model, and simulations that would stand some scrutiny?

3. How much will it cost for you to carry out a good, quality review?

4. What are your initial impressions of the studies?

I will be sending Dr. Wilen the following manuscripts and preliminary work products and provide you with a copy of the cover letter to Dr. Wilen.

1. *Legislative Review of the Alaska Salmon Enhancement Program*, January 1993, Draft Chapter IX - Economics. Alaska State Senate Special Committee on Domestic and International Commercial Fisheries.

2. *A Benefit-Cost Analysis of the Alaska Salmon Enhancement Program*, December 1992, final report by Boyce, Herrmann, Bischak, and Greenberg.

11-K6LH

3. Cost-Benefit Analysis (CBA) annual and aggregated net benefit output tables, November 1992, draft by John Boyce.

4. *An International Marketing Model for Alaskan Salmon*, November 1, 1992, draft by Herrmann and Greenberg.

5. Executive Summary, *An International Marketing Model for Alaskan Salmon*, December 15, 1992, draft by Herrmann and Greenberg.

6. Demand Model Simulation Model Code in SAS, December 1992, draft by Mark Herrmann.

7. Demand model output prices by species, year, policy case, region, and aggregated regions, December 1992, Mark Herrmann.

8. Using Participation Data to Estimate Fishing Costs for Commercial Salmon Fisheries in Alaska, November 1992, draft by John Boyce.

9. ADF&G technical comments to Senate Special Committee on Domestic and International Fisheries from Jeffery P. Koenings, February 4, 1993.

10. Reimbursable Services Agreement Contract Specifications and Request for Proposals for Software Development and Policy Analysis of a Benefit-Cost Analysis of the Statewide Enhancement Program.

Thank you for your interest in this matter.

Sincerely,

Jeff Hartman
Economist

cc: Geron Bruce
Bob Burkett
Johnny Holland
Jeff Koenings

Justification for Technical Review of UAF CBA Model

by Jeff Hartman, 2-10-93

It is customary in technically challenging econometric studies, or where there are significant policy implications from studies, that contracting agencies seek independent technical reviews. It is also a prudent action when the reviewers of the contracts express some uncertainty about their own ability to interpret the findings. The UAF CBA meets and exceeds all three of these criteria.

The demand model by Herrmann and Greenberg has over 50 equations and requires about 16 hours to estimate on a 486 33Mh. Some of the econometric techniques used in the "block 1" estimates are new, and few economists have extensive experience with them.

Two of the four economists reviewing the contracts, Kurt Schelle and Ben Muse, possess a Ph.D. in economics and have extensive experience in fisheries economics. They have expressed reservations about their abilities to interpret certain new techniques used in the demand model. Though I have spent several hours trying to unravel the block 1 and 2 estimates, I also cannot confidently say that the methods are or are not technically sound approaches to generating long-run projections of price response. I have never reviewed an econometric model that is this nested or uses such novel statistics.

Other technical questions, both theoretical and methodological, have been raised about the fishing cost and population models used in the studies. Finally, the net benefit algorithms, the summarizations of input data, and statistical significance of the net benefit point projections have been questioned.

All of these issues, by themselves, lead to the need for some independent, technical review. However, the timing of the review with respect to whether it occurs before or after the studies are released appear to be a critical concern because of possible policy implication and the high potential of misinterpreting the model implications.

A study that had severely negative implications about the future for Alaska's salmon industry could, at this time, have a strong impact on private and public sector decisions. The study could have an effect on Government policy for the enhancement program, fishery management, loans to fishermen, bycatch of salmon, marketing of seafood, and the U.S./Canada Pacific Salmon Treaty. Perceptions of private lenders and fishermen may also be impacted, along with limited entry permit markets.

With these issues in mind, I am supportive of the proposal to develop an independent, technical review of the full cost-benefit analysis. I would suggest that this review begin only after the work products are finalized to the point that a detailed technical review can actually occur. The primary question that we should be asking in this review is if the models and existing simulations are sufficient for making major directional changes in Alaska salmon management and enhancement policies.

Additional discussions on the proposed technical review.

1. On 2-3-92, I contacted CFEC (Kurt Schelle) and asked if CFEC would be willing to act as the contracting agent for a technical review of the CBA studies. He said that he would consider it, but would have to discuss it with others at the Commission. I felt that since they have technical ownership of all of the materials and work products of the study (they were the contracting agency for the original modeling), that CFEC would be the best group to contract through for an impartial review. I believe that CFEC should be given the full authority to choose the contractor and the questions to be asked. I trust them to make sure that the questions to the contractor should be framed in an objective manner.

2. I talked with our contract people to see how difficult it would be to AJE $2,500 over to CFEC to carry out a review. They said that it would be fairly straightforward.

3. I contacted James Wilen, my first choice as a technical reviewer. Wilen is extremely knowledgeable about salmon demand models and fishing cost models. He is familiar with the work of Mark Herrmann, Ron Mittelhammer, and John Boyce which gives him a considerable head start in being able to carry out an efficient review. He has worked for the AG's office on the oil spill economic damage assessment, specializing in commercial fisheries. He is a long-time friend of Don Collinsworth and knows much about how Alaska fish politics work. He has a current background in econometrics and is familiar with the Baysian bootstrapping and other new econometric techniques used in the demand models.

Wilen believes that it is a good idea to get the studies reviewed if they could have important policy implications. He said that it would probably take a week of intense work, but if he could see some of the draft reports, he would be able to give us a more precise time estimate. I have received permission to send him some of the draft copies.

If it is alright to ship them to him, I would ask him:

1. Would it be worth investing the time to review the studies?
2. How long would it take?
3. How much would it cost?
4. What are your initial impressions?

My impressions about other possible researchers for a Technical Review include:

Ron Mittelhammer is probably not impartial since he put Herrmann onto these techniques in the first place. Also, he is a co-author and major professor of Herrmann on the publications that initially resulted in the block 1 estimates. I understand he is a very good econometrician, but don't know him personally.

Biing-Hwan Lin is not really available. He now works for the federal government on other issues, and also has been a co-author on related studies with Herrmann.

I have not yet contacted Jim Anderson. He may be interested and probably has sufficient skills. I do not know him very well. Also, I do not know if he could be trusted to write a good summary. I was not that impressed with a piece he did for Commerce a few years ago.

ISER is probably out because they competed for the original contract. I do not feel that they would be very objective, since there seems to be some competition between the campuses.

Terrence Smith is now at Woods Hole. He would probably have a good overall understanding of the technical aspects of the CBA, but I doubt would have specific knowledge about the new techniques used in the demand model.

Ira Strand worked on commercial fisheries damage assessment for the feds after the *Exxon Valdez* oil spill. I understand that he is a strong theorist. I do not know about his other skills and have not contacted him.

Gardner Brown is not known for his econometrics, which may be a real problem in the review. He is very opinionated, understands Alaska fish politics, and is known to be very practical. He is also a clear writer, all of which would probably be an advantage.

Lou Querillo is probably not quite strong enough in the newest wave of econometrics techniques to be a prime contender. I do not believe that he would have many new comments that Ben, Kurt, or I would not have identified. I also doubt that he would have the time. I also do not know what is involved for transferring review funds to NMFS.

Jim Wilen is as close to perfect for the job as I can imagine. He has a strong reputation as an impartial reviewer and seems to have a significant amount of prior knowledge of Boyce and Herrmann's work. He says that he is interested in doing the job, would be impartial and fair, but not pull any punches. He clearly has the econometric skills to do the work. I know him to be an excellent communicator and writer.

MEMORANDUM **DEPARTMENT OF FISH AND GAME**
GENETICS PROGRAM

TO: Molly McCammon **DATE:** February 5, 1992

SUBJECT: Chapter VIII

FROM: Jim Seeb, Principal Geneticist, FRED 267 3885

I'm in meetings and don't have a lot of time. I'll review the document tonight if you still need comments. The document is damn good, by the way--especially the "options".

Pg 2, para 1. I don't understand "success of crossbreeding." Do you mean the "effects of interbreeding?" I have some concern about this paragraph--may we talk?

Pg 3

Policy para 2. Perhaps delete "importance" in sent. 1. Delete the last sentence "The policy also includes considerations . . ." This sentence overstates the importance of a trivial research agenda item

Policy para 3, sent 2. replace "into wild or enhanced" with "between."

Pg 4 para 2

replace "is" with "was" twice in sentence 1. Perhaps add a sentence at the end that says something like "The Commissioner is attempting to clarify some of the flexible guidelines in the revised policy incorporating ~~some of the~~ knowledge gained from recent studies of the population genetics of salmonids."

I'm sorry I don't have more time today. Please call if you have any questions. I feel that the document is fine as it stands. I hope that these comments help, and I would be glad to give you more input if given the chance.

Do you have a copy of our draft genetics document from the Cordova meeting?

FEB 05 '92 16:35 DEPT FISH & GAME

FRED Special Report

Alaska Department of Fish & Game
GENETIC POLICY
by
Genetic Policy Review Team
Bob Davis - ADF&G, FRED, Chairman

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

Alaska Department of Fish & Game

GENETIC POLICY

by

Genetic Policy Review Team
Bob Davis - ADF&G, FRED, Chairman

Other Team Members:

Brian Allee - PWSAC, Cordova
Don Amend - SSRAA, Ketchikan
Bruce Bachen - NSRAA, Sitka
Bill Davidson - SJC, Sitka
Tony Gharrett - UAJ, Juneau
Scott Marshall - ADF&G, Comm. Fish
Alex Wertheimer - NMFS, Auke Bay Lab

Approved:

Don W. Collinsworth

Don W. Collinsworth, Commissioner
Alaska Department of Fish and Game

Date: 6·11·85

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INTRODUCTION

Alaska's valuable salmon industry relies on production from wild systems and, increasingly, on fish produced by aquaculture programs. The importance of maintaining healthy wild stocks and implementing successful enhancement activities underlies the need for an effective genetic policy. The genetic guidelines created to steer Alaska's aquaculture efforts were established in the mid-70's and have been reviewed to ensure that they reflect current knowledge, and goals. A revised genetic policy has been established that contains guidelines, supporting information and recommendations.

The genetic policy contains restrictions that will serve to protect the genetic integrity of important wild stocks. Certainly in Alaska where wild stocks are the mainstay of the commercial fishery economy, it is necessary to protect these stocks through careful consideration of the impacts of enhancement activities. Another important aspect of the genetic policy is the orientation towards increasing the productivity of enhancement programs in the state. Adherence to the guidelines will help maintain adequate genetic variability ensuring that the enhanced stock will be able to adapt to changing environmental conditions. The policy also includes considerations for selective breeding for desirable characteristics.

Due to the limited amount of information available on the genetic impacts of salmon enhancement on wild stocks, much of the basis for these guidelines is theoretical or based on work done with other species. Consequently, the most important considerations used in writing the guidelines are presented as a mechanism for illustrating the intent of the policy. An understanding of the rationale behind the policy is imperative to its effective application to individual cases under the very diverse conditions found in Alaska.

The importance of the genetic guidelines will continue to increase as aquaculture activities expand their production. This policy represents a consensus of opinion and should continue to be periodically reviewed to ensure that the guidelines are consistent with current knowledge. By doing so, we will be able to meet the goal of greater fish production through enhancement while maintaining healthy wild stocks.

POLICY STATEMENT

I. Stock Transport

A. Interstate: Live salmonids, including gametes, will not be imported from sources outside the state. Exceptions may be allowed for trans-boundary rivers.

B. Inter-regional: Stocks will not be transported between major geographic areas: Southeast, Kodiak Island, Prince William Sound, Cook Inlet, Bristol Bay, AYK and Interior.

C. Regional: Acceptability of transport within regions will be judged on the following criteria.

1. Phenotypic characteristics of the donor stock must be shown to be appropriate for the proposed fish culture regions and the goals set in the management plan.

2. No distance is set or specified for transport within a region. It is recognized that transplants occurring over greater distances may result in increased straying and reduce the likelihood of a successful transplant. Although the risk of failure affects the agency transporting the fish, transplants with high probability of failure will be denied. Proposals for long distance transport should be accompanied by adequate justification for using nonlocal stock.

II. Protection of Wild Stocks

A. Gene flow from hatchery fish straying and intermingling with wild stocks may have significant detrimental effects on wild stocks. First priority will be given to protection of wild stocks from possible harmful interactions with introduced stocks. Stocks cannot be introduced to sites where the introduced stock may have significant interaction or impact on significant or unique wild stocks.

B. Significant or unique wild stocks must be identified on a regional and species basis so as to define sensitive and nonsensitive areas for movement of stocks.

C. Stock Rehabilitation and Enhancement

1. A watershed with a significant wild stock can only be stocked with progeny from the indigenous stocks.

2. Gametes may be removed, placed in a hatchery, and subsequently returned to the donor system at the appropriate life history state (eyed egg, fry or fingerling). However, no more than one generation of separation from the donor system to stocking of the progeny will be allowed.

D. Drainages should be established as wild stock sanctuaries on a regional and species basis. These sanctuaries will be areas in which no enhancement activity is permitted except gamete removal for broodstock development. Use of such reservoirs for broodstock development should be considered on a case-by-case basis, and sliding egg take removal schedules applied to such systems should be conservative.

E. *Fish releases at sites where no interaction with, or impact on significant or unique wild stocks will occur, and which are not for the purpose of developing, rehabilitation of, or enhancement of a stock (e.g., releases for terminal harvest or in landlocked lakes) will not produce a detrimental genetic effect. Such releases need not be restricted by genetic concerns.*

III. *Maintenance of Genetic Variance*

A. *Genetic diversity among hatcheries*

1. *A single donor stock cannot be used to establish or contribute to more than three hatchery stocks.*

2. *Off-site releases for terminal harvest rather than development or enhancement of a stock need not be restricted by III.A.1, if such release sites are selected so that they do not impact significant wild stocks, wild stock sanctuaries, or other hatchery stocks.*

B. *Genetic diversity within hatcheries and from donor stocks*

1. *A minimum effective population (N_e) of 400 should be used for broodstock development and maintained in hatchery stocks. However, small population sizes may be unavoidable with chinook and steelhead.*

2. *To ensure all segments of the run have the opportunity to spawn, sliding egg take scales for donor stock transplants will not allocate more than 90% of any segment of the run for broodstock.*

GUIDELINES AND JUSTIFICATIONS

I. Stock Transport

A. Interstate: It is generally accepted that population of salmonids which have existed over many generations in a given watershed have evolved traits that make them best adapted for survival in that environment. The greater the distance that a population is transferred from its native environment or the greater the difference in environmental conditions between the donor and transplant stream, the less likely the genetic characteristics of the population will fit the new environment. If the fitness of the population is indeed reduced in the new environment, then the probability of the transplant succeeding would be affected. In addition, interbreeding of a transferred stock with indigenous stocks could transfer gene traits that would reduce the fitness of the native populations. In many states, discrete stocks cannot be identified because excessive movement and interbreeding have already occurred. The State of Alaska, therefore, desires to protect and develop local stocks by restricting the movement of live fish or eggs into the state. There are, however, several trans-boundary rivers penetrating British Columbia, Canada, that flow into the state of Alaska. In some instances, donors from these stocks might fit a well-designed management plan.

B. Inter-regional: The environment can vary greatly from one region to another in a state as large as Alaska. For similar reasons given in I.A. above, the transfer of fish from one region to another is restricted. Consideration may be given to regional border areas, especially when no suitable donor stock is available within a region.

C. Regional: Although it is recognized that indigenous stocks are best for donor stock development, there have been numerous successful transplants, especially if the environment at the new site is similar to that of the donor stock and distance between the sites is not great. There is insufficient scientific data to predict how far or how diverse the environment must be before a negative impact will occur. However, it is believed that within a region site matching opportunities may be available. As site matching characteristics decrease and transplant distance increases within the regional borders greater justification is required for the proposed transplant. The following should be considered when selecting a donor stock:

1. Matching: Phenotypic characteristics of the donor stock should be matched to the environment at the site and to the management goals. Water chemistry and temperature profiles should be considered. Island stocks should be matched to other islands or to short rivers of comparable characteristics where possible. Time of spawning and fry emergence should be matched or compensated with the hatchery temperature required. Any deviations should be addressed and justified in the permit application or the annual management plan.

2. Migration Routes: The probable migration routes and potential user groups should be identified. The applicant must determine a probable migration route based on the migration route of the proposed stock and characteristics (topography) of the transplant site. Coded wire tagging of hatchery releases can determine the accuracy of migration route predictions as well as assess possible impact on local stocks.

II. Protection of Wild Stocks

A. Prevention of detrimental effects of gene flow from hatchery fish straying and interbreeding with wild fish.

Straying of hatchery fish released at the hatchery or off-station can potentially impact the fitness of wild fish populations through interbreeding of wild and hatchery fish. This assumes that hatchery and wild fish are adapted to different environments and either would presumably be less fit in the environment of the other and that hybrids would be less fit for either environment. Wild stocks have presumably been rigorously adapted to their native environment. Because of the large number of loci involved in the adaptation, many "successful" combinations of genetic information are possible along with the enormous number of "unsuccessful" combinations. Hybridization between discrete populations may produce a stock that has reduced fitness and therefore reduced production. Hatchery fish have been subjected to selection pressure for survival within artificial culture regimes, and may also have been originally derived from another stock adapted to totally different conditions than the impacted wild stock. Continued influx of hatchery fish together with the return of hybrids may alter the wild gene pool, reduce stock fitness, and thus threaten the survival of the wild population.

An alternative perspective is that hatchery strays will have little genetic impact on wild stocks. The influx of new genetic material through straying is a natural process in the development and expansion of salmon populations. If adaptation of the natural population is indeed very specific and selection is intense, then

selection will favor and maintain the genetic complex of the wild populations. If adaptation is less specific and less intensive, then the genetic impacts from gene flow are insignificant. It is true that some straying occurs among adjacent wild populations and in most cases has occurred for a long enough time that such populations are quite similar genetically. However, situations in which transplanted stocks are involved are not analogous, as transplanted stocks would be less similar and gene flow would have a more profound effect. It is also true that the impact of introgression into the wild gene pool of genes from fish transplanted from a radically different environment may be limited by natural selection. Again the situations of concern do not necessarily lie near this extreme; hybrids and strays may be fit enough to dilute or replace the wild genome. Inherent homeostatic mechanisms for gene expression may compensate for some genetic influx.

The magnitude of straying relative to the size of the wild run is the most important criterion, as massive spawning by hatchery strays may jeopardize a wild population by displacement on spawning habitat and superimposition of redds, as well as, genetic influx. A conservative management approach dictates avoiding release sites where large numbers of hatchery strays can be expected to interact with significant or unique wild stocks. This approach can be achieved by spatial or temporal isolation of the hatchery and wild stock.

B. Regional designation of significant and unique wild stocks.

The magnitude of salmon populations varies between watersheds from intermittent runs maintained by

straying to hundreds of thousands of fish. In evaluating the impacts of salmon enhancement projects, consideration must be given to the potential of detrimental effects from straying and intermingling with wild populations and possible resultant loss of wild production. Such consideration must take into account the benefits of the enhancement activity and the significance of the wild stocks impacted. Designation of criteria for runs of fish that are considered significant would greatly expedite the evaluation process. However, "significance" must be defined not only by the magnitude of the run, but also in the context of local importance and utilization. A small sockeye salmon stock near a village in southeast Alaska may be "significant", whereas the same size population may be too small to be considered a manageable entity in Bristol Bay. 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.

C. Stock rehabilitation and enhancement.

1. A watershed with significant wild stocks can only be stocked with progeny from the indigenous stocks. Rehabilitation of a watershed implies that there is insufficient production in habitat that formerly maintained a stock of some magnitude. Unless the indigenous stock has gone to extinction, use of an exogenous stock has potential for genetic damage noted in II.A. This damage will be exacerbated by the imprinting and homing of the transplanted stock to the impacted watershed, and potential displacement of wild

juveniles by the exotics stocked in the rearing habitat.

Enhancement of habitat not naturally accessible to salmon involves stocking eyed eggs, fry, or fingerlings, thus gaining production from this unutilized habitat. Where the inaccessible habitat is located above barriers on watersheds that maintain significant natural populations, stocking nonindigenous populations again has potential for genetic impacts noted in II.A., exacerbated by imprinting and homing of the transplanted stock to the watershed. For both rehabilitation and above barrier stockings, use of the indigenous stock alleviates these concerns.

2. When enhancing a stream using the indigenous stock, the fish used for stocking shall not be removed from the wild system to a hatchery for more than one generation.

Hatchery incubation and rearing select for a limited set of biological and behavioral traits which are not necessarily the most suitable for survival in the wild environment. Because of this potential for such selection, the transfer of hatchery fish to rehabilitate or enhance stocks in depleted or underutilized watersheds runs the risk of altering the genetic character of the wild stock, even if the indigenous stock was the original donor stock for hatchery population. By restricting the separation between the transfer to the hatchery and the stocking to no more than one generation (e.g., eggs taken in a given year are cultured to fry or fingerling release at the hatchery; eggs or fish from the returns to the

hatchery of this donor transplant are used for stocking), the risk of negative effects due to selection in the hatchery are minimized.

D. Establishment of wild stock sanctuaries.

As roted in preceding sections, there is concern that hatchery culture of salmon through their freshwater (and in some cases, initial estuarine) life history phases may select for a limited set of biological traits that are not suitable for wild populations. Loss of genetic variability through intensive inbreeding for domestication and desired traits has often resulted in detrimental genetic effects in agronomy and agriculture, such as reduced resistance to disease or adverse environmental conditions. Original wild strains can provide the genetic variability needed to outbreed domestics and alleviate inbreeding depression. Because there is potential for detrimental impacts due to reduction of genetic variability, there is a need to preserve a variety of wild types for future broodstock development and outbreeding for enhancement programs. Designation of watersheds where hatcheries or hatchery plants are not allowed would allow wild stocks within these watersheds to be subjected to natural selection only, within the life history phases cultured at hatcheries. These watersheds would be "gene banks" of wild-type genetic variability.

III. Maintenance of Genetic Variance

A. Genetic diversity among hatcheries.

There is general agreement that by introducing and maintaining a wide diversity of wild donor stock

populations into the hatchery system that the prospects for long term success of the hatchery program in Alaska will be enhanced. Diversity tends to buffer biological systems against disaster, either natural or man-made. Developing and maintaining hatchery broodstock from a wide variety of donors will buffer the hatchery system against future catastrophes. Agricultural crop production in the U. S. provides a prime example of the dangers of genetic uniformity.

In an effort to increase yield, plant breeders have come to rely on a few highly productive strains. In 1970 approximately 15% of the corn production in the United States was lost to corn blight. The corn blight responsible, a mutant of the normal blight causing fungus, did not attack all strains. Only one strain of corn was vulnerable, but that strain of corn was grown by nearly every farmer in the country. Breeders were able to recover from the corn blight epidemic by replacing Texas cytoplasm with normal cytoplasm. Recovery was rapid because adequate genetic variability was available. There are other examples.

How does this relate to salmonid culture? Salmonid stocks apparently differ in levels of disease resistance, temperature tolerance, acid tolerance, and in their response to artificial selection. It seems imprudent to assume that conditions similar to those found in agriculture will not occur in aquaculture. In addition, the ability to genetically improve hatchery broodstock performance in the future will depend on the availability of genetic variability such as is found among wild salmonid stocks. A hatchery system with a variety of diverse broodstocks will be a valuable resource.

Genetic diversity does not guarantee protection from disaster, but uniformity seems to invite catastrophe. Local failures are inevitable within the hatchery system. It seems prudent to provide the system with a level of insurance by developing and preserving diversity among hatcheries.

Off-site releases for terminal harvest, whether for the commercial fishery or for a put and take sport fishery should have no adverse genetic effect if they are released at sites selected so that they do not impact significant wild stocks, wild stock sanctuaries or other hatchery stocks. The success of this type of release from a genetic standpoint depends on the ability to manage and harvest the return. If returns can not be harvested, increased straying may result which might lead to an impact on wild stocks at a greater than expected distance from the release site.

B. Genetic diversity within hatcheries and from donor stocks.

There is a general consensus among geneticists that fitness (reproductive potential) is enhanced by heterozygosity (genetic variability). Any loss of genetic variation will be accompanied by a concomitant reduction in fitness. Genetic variation allows a population to adapt to a changing environment or to adapt to and colonize a new environment. Available genetic variation determines how rapidly a population will respond to either artificial or natural selection. On the other hand, selection, inbreeding and random genetic drift will reduce genetic variability in a population.

Natural selection, that is selection for fitness, is a continuing process and should not be so intense that it

has a significant effect in reduction of genetic variation, unless the population is in a new and quite different environment. Artificial selection on the other hand can be very intense, but can either be avoided or designed to assure that possible negative effects to fitness are offset by increased production efficiency due to the selection program, and by more efficient culture techniques. Inbreeding due to the deliberate mating of related individuals can be easily avoided in salmon hatcheries. Undoubtedly, in hatcheries and possibly in natural stocks the most important cause of loss of genetic variation is random genetic drift. In hatcheries reduction of genetic variation caused by inbreeding and genetic drift can easily be avoided by using adequate numbers of spawners.

Random genetic drift in general refers to fluctuations in gene frequency that occur as a result of chance. Such fluctuations occur, especially in small populations, as a result of random sampling among gametes. The amount of change but not the direction of change, can be predicted. The rate of this change is related inversely to effective population size (N_e). The smaller the effective population size the greater the fluctuation in gene frequencies. In small populations random genetic drift can result in inadvertent loss of genetic variability which may significantly reduce the fitness of the population.

Effective population size (N_e) is defined as the size of an idealized population that would lose genetic variability at the same rate as the sample population. An idealized population is one in which there is no

mutation or selection, there are equal numbers of males and females, mating is random, etc. Obviously it is very unlikely that any natural population will meet all criteria for an idealized population.

Breeding structure of a population can profoundly affect the rate at which genetic variability is lost. However, we can determine the effective breeding size (N_e) for breeding structures and obtain the rate of inbreeding (ΔF) as

$$\Delta F = 1/2N_e$$

so the consequences of breeding structure can be related to the loss of variation.

Many breeding structure variations can influence the effective population size. Four seem likely to operate in a salmon hatchery population: (1) numbers of males and females in the breeding population; (2) unequal numbers in successive generations; (3) nonrandom distribution of offspring among families; and (4) overlapping generations. These are discussed in greater detail in Appendix A.

Any of these variations in breeding structure may have a marked effect on N_e. Although it may be impossible to control or even to measure variation in family size it is important to keep in mind the relationship to effective population size. Breeding plans that would aggravate or increase the variation of family size should be avoided. The effect of overlapping populations is to increase the effective population number, in that individuals mating in different years contribute to greater diversity. For example, it would

take a larger number of pink salmon each year to maintain N_e = 400 than it would sockeye salmon.

The factor having the greatest potential effect in the hatchery and over which we have most control is sex ratio. As the formula indicates (Appendix A) the effective population size is affected most by the numbers of the least frequent sex. It is important to consider this in the breeding plan. In salmon, because a male can be used to fertilize the eggs of a large number of females, there is a temptation to do so. This temptation should be moderated by the necessity to maintain an effective population size which will assure that adequate genetic variation is maintained in the population. A minimum effective population (N_e) of 400 should be maintained. At this size the rate of inbreeding will be 0.125 percent per generation which should not have a significant effect on the long term fitness of the population.

In some cases, for example with chinook and steelhead, small population size may be unavoidable. In such cases a plan should be developed to offset the effects of small population size by infusion of genes from a source outside the hatchery population, such as the original donor source. Help in designing these breeding plans can be obtained from the Principal Geneticist, FRED Division, Alaska Department of Fish and Game.

While developing hatchery stocks from wild donor sources it is important that the genetic variability in the donor stock be protected. Cropping of the early or late run segments of a donor stock can change the timing of that run, which will reduce genetic variability of the population and may be detrimental to the stock's prospects for long term survival. To prevent

such selection, sliding egg take scales for donor stock transplants should allocate no more than 90% of any segment of a run for broodstock.

RESEARCH

The necessity for much of this policy arises from our ignorance of the genetics of wild salmon populations and the effects of their domestication in hatcheries. The policy is based more on extrapolation from other disciplines such as agriculture than from first-hand knowledge of our resource. As a result, the policy is a somewhat conservative interpretation of these data in order to assure the long-term viability of salmon populations. The Committee has identified several areas in which specific knowledge would clarify this policy and contribute to the effectiveness of salmon enhancement. The Committee encourages cooperative research efforts among the university, state, federal and private sectors directed toward the general areas listed below.

1. Development of performance profiles of hatchery stocks and potential for genetic improvement. Information about stocks kept in culture will be useful in several ways. If taken in a standard manner, the data will be useful in determining the extent of variability in the species and will aid in the choice of stock to be used for outplanting or transplanting. The information will also be helpful in maximizing the production of a particular facility.

2. Potential for genetic improvement of cultured stocks. A sequel to the cataloging of the variability within and among stocks will be to experimentally assess the potential for genetic improvement by selective breeding. To do this, it is necessary to determine the heritabilities for traits of interest, that is the part of the phenotypic variability present in a population which results from genetic (heritable) causes as opposed to environmental causes. Traits such as size of adults, age of return and various timing parameters are particularly interesting to industry.

Application of artificial selection is responsible for the enormous advances that have been made in agriculture; the potential also exists in aquaculture.

3. Assessment of the effect of introgression of genes from hatchery fish into wild populations. To examine this effect, one must first have an estimate of the rate of straying and the factors that influence straying. Such factors might include transplant distance, run strength, source of the hatchery stock and year-to-year environmental differences. By using a genetically marked stock, one can monitor the flow of "hatchery genes" into other populations. Because the effect of such introgression may develop over time, it is necessary that such an experiment be conducted over several generations. For this kind of study, it may be necessary to develop a means for marking fish cultured at production levels.

   The second part of this problem is to establish the impact of introgression. A range of potential interactions is possible ranging from introgression between two unrelated stocks to the introgression of fish subject to the selective pressures of a hatchery back into the wild stock from which they were derived. Research to examine these effects could best be done in an experimental hatchery where hybrid stocks could be produced and all releases marked. Port sampling and stream walking would be necessary to evaluate survival, straying and other phenotypic effects.

4. The effects of inbreeding and maintenance of inbred lines. Accompanying the artificial propagation of a species is the potential for inbreeding, loss of genetic variability and increased homozygosity. Information pertinent to the extent of inbreeding depression that results from various levels of inbreeding is necessary in determining adequate effective population sizes. This is especially important for species

for which a large effective population size is difficult to maintain. In addition, this information would permit a judgement on the efficacy of enhancing very small remnant populations. This work could be done both by performing crosses designed to accomplish some level of inbreeding, and by the maintenance of small randomly breeding populations. In both cases, it is important to keep careful controls.

APPENDIX A

Appendix A

The relationship of breeding structure, effective population size, and rate of inbreeding.

Breeding structure can profoundly affect effective breeding size (N_e) of a population. We can, at least in theory, determine the effective breeding size for many breeding structures and obtain the rate of inbreeding (ΔF) as

$$\Delta F = 1/2N_e$$

directly relating variation in breeding structure to loss of genetic variation.[1/]

The following demonstrates the consequence of some breeding structures to effective population size.

Number of males and females: Unequal numbers of males and females in the breeding population reduce effective population size. Sex ratio is related to effective population number (N_e) as

$$N_e = 4N_mN_f/(N_m + N_f)$$

where N_m and N_f refer to the total number of males and females respectively. The effective population size is strongly influenced by the number of the least frequent sex.

Unequal numbers in successive generations: If the numbers of breeding individuals is not constant in successive generations the mean effective number is the harmonic mean of the number in

1/ See D.S. Falconer. 1981. Introduction to Quantitative Genetics. Longman Inc., New York.

each generation. Over generations the effective number is approximately,

$$1/N_e = 1/t(1/N_1 + 1/N_2 + 1/N_3 + \ldots\ldots 1/N_t).$$

The generation that has the smallest number will have the largest effect.

Nonrandom distribution of offspring among families: When there is large variation in family size the next generation is made up of the progeny of a smaller than expected number of parents. This can be related to loss of genetic variation through effective population number as

$$N_e = 4N/(V_k + 2)$$

where V_k refers to the variance in family size. When variation of family size V_k is equal to 2, then $N_e = N$. When the number of males and females are unequal, the variance of family size may be unequal in the two sexes and

$$N_e = 8N/(V_{km} + V_{kf} + 4)$$

where V_{km} and V_{kf} are the variance of family size for males and females respectively.

Overlapping generations: In species other than pink salmon generations are not discrete, they are overlapping. When generations overlap the effective population size is

$$N_e = 4N_cL/(V_{km} + 2)$$

where L is the generation time and N_c is the number of individuals born in a year, that is the cohort size. The cohort size N_c is related to the total number (N_t) by $N_c = N_t/E$ and E is the mean age at death. As before V_{km} is the variation of family size.

The effect of unequal sex ratio and unequal numbers in successive generations on population size can be easily estimated. On the other hand it will be difficult or perhaps impossible to estimate the variance of family size. Nevertheless, we should keep in mind the relationships of family size and overlapping generations. Overlapping generations will in general increase the effective population number in that individuals mating in different years contribute to greater diversity. Variance of family size can radically reduce effective population size. Procedures that contribute to variance of family size or separation of year classes should be avoided.

FRED Reports

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Alaska Department of Fish and Game
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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 broodstock 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 broodstocks.

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 long-term 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

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 then 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 population 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 occurs 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 broodstock 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 broodstock 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 broodstocks.

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 broodstock from excess eggs of an existing broodstock 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 broodstocks 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 broodstocks. 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 broodstocks 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.

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Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska: Genetic Considerations

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Introduction

The central goal of fishery management is to increase and stabilize productivity of fishery resources. We know from experience that rapid expansion of production usually results in the eventual collapse of the fishery (option A in Figure 1). In contrast, a more measured rate of increase can be sustained and, thus, is preferred in the long-term (option B Figure 1). Option A shows the result of having the single goal of maximally increasing production. Option B shows the result of increasing production while also protecting the genetic integrity of wild stocks. It is often difficult to resist the opportunity to maximize production in the immediate future. Nevertheless, history demonstrates that this is an unwise choice for a variety of reasons.

For example, the abundance of coho salmon in the lower Columbia River below the hydroelectric dams was greatly increased by the production of very few hatchery stocks. This enhancement was accompanied by greatly increased fishing pressure that, in combination with straying from hatchery stocks, has resulted in the extinction of wild stocks of coho salmon in the lower Columbia River. In addition, the total US Pacific coast catch of these fish has decreased to approximately one-half million fish in 1990 from a peak of over four million fish in the early 1980's. This has been accompanied by a reduction of nearly 50% in the number of eggs per female since 1945 (Washington, this meeting).

The Columbia River situation with coho and other salmon species has been incorrectly labeled as "meat vs. museums". That is, we can either use the salmon as a resource or lock-them-up to preserve their genetic diversity. This is untrue and dangerous; if we don't protect genetic diversity there won't be any resource to use in the future. A group of biologists at a recent workshop concluded that "sustainable increases in salmon and steelhead productivity in the Columbia River Basin can only be achieved if the genetic resources required for all forms of production, present and future, are maintained in perpetuity"

(Riggs et al. 1991).

The Alaska Department of Fish and Game (ADF&G) Genetic Policy (1985) is based upon the principle that the long-term productivity of Alaska's fisheries resources depends on the genetic integrity of wild stocks. Wild stocks are the foundation of the commercial fishery economy in Alaska. More importantly, wild stocks contain the genetic resources necessary for continued production in an uncertain future.

The Policy is based upon the principle that diversity buffers biological systems against disaster, either natural or human-induced (page 13). The present document discusses the biological basis for maintaining genetic diversity both within and between local populations of salmon in Alaska. We first outline possible interactions between wild and enhanced populations. We next consider the importance of maintaining genetic diversity in enhanced stocks of salmon. Finally, we conclude with a series of recommendations to protect these important resources.

Enhanced and Wild Interactions

Hatchery supplementation of natural production of salmonids has been practiced for well over 100 years. This supplementation has increased the productivity of salmonid fisheries in some instances. However, problems involving long term survival and loss of diversity of wild stocks have arisen as a direct result of these practices. The conflicts are both genetic and non-genetic.

The genetic concerns are derived from the large number of distinct local populations that have arisen from the strong homing instincts of anadromous salmonids and the differential patterns of natural selection among rivers. Reproductive isolation of these populations in their distinct environmental settings has resulted in genetic adaptations to the local environment. As a result of both inadvertent and intentional unnatural selective pressures in the hatchery environment, hatchery stocks often diverge genetically from their wild counterparts.

Some hatchery fish will inevitably stray into wild populations. The genetic outcome of this straying is unpredictable. Hatchery fish that successfully produce progeny when they interbreed with wild fish, may reduce fitness of the locally adapted populations. Such reduction may result from the displacement of locally adapted genes or the disruption of coadapted gene complexes. Hatchery fish that do not successfully produce progeny when they interbreed with wild fish directly reduce the productivity of that wild population, and may - in the extreme - lead to its extirpation. Introgression can only be detected through genetic monitoring.

Hatchery practices may erode the homing precision of the enhanced populations resulting in an increased tendency to stray into wild populations. It is important to emphasize that even a small straying rate from a large hatchery may produce a large number of strays in comparison to local wild stocks. If the number of strays is large enough, it will almost certainly overwhelm the native fish, regardless of any survival differential favoring the wild stock.

Large numbers of cultured fish also have management implications. In the absence of programs that monitor interactions of enhanced and wild fish, large numbers of hatchery strays can mask the decline of wild fish. Consequently, the estimates of escapement and returns-per-spawner made by fisheries managers may be inaccurate. Furthermore, behavioral interactions with hatchery fish may affect the migratory behavior of wild fish; a disproportionate abundance of hatchery fish may increase the likelihood of interception of wild fish near the hatchery.

The objective of hatchery management is to increase and stabilize the total harvest. Unfortunately, hatchery stocks tolerate much higher exploitation rates than wild stocks. As a result, many wild stocks commingling with hatchery fish during harvest may be exploited at intolerably high rates. Such management conflicts should be addressed prior to development of a production facility. Wild salmon may also be intercepted in hatchery cost-recovery fisheries and brood stock collections.

There are a number of additional biological concerns related to hatchery and wild stock interactions. These include increased potential for disease transmission from hatchery to wild stocks, potential of competition for food resources which may be limiting particularly for young fish, and the attraction beyond normal levels of predators.

Hatchery Broodstock Management

The productivity (fitness) of a system of hatcheries and wild stocks depends on variation among populations. It is likely, for instance, that different stocks may feed in different parts of the marine environment or may use an area at different times; a system that relies on a variety of stocks is more likely to take advantage of localized areas of high productivity and food and to avoid density-dependent effects of overpopulating such localized areas.

Similarly, an important component of the productivity of a stock is the phenotypic variability for numerous traits such as size, age, migration and spawning times, emergence times, etc. Most such phenotypic traits have a significant genetic component. For a stock which faces unpredictable environments from generation to generation, genotypic and phenotypic variation in a population increases the likelihood that its members will distribute to different places and times where opportunities for food, growth, and survival may present themselves.

The importance of genetic variability, both within stocks and between stocks, has implications both for donor stock selection and for the actual management of broodstocks. Donor stocks must be chosen judiciously to optimize their hatchery performance and minimize their effects on local wild stocks. Broodstock management practices in hatcheries can alter the genetic composition of and reduce the genetic variation present in a hatchery stock. The primary causes are inbreeding and selection, whether inadvertent or directed. Inbreeding which results from using too few parents can rapidly reduce genetic variability. Domestication selection, an unavoidable consequence of hatchery production or inadvertent selection of broodstock

(e.g. for size or timing) usually entails some loss of variability. The rate of loss of genetic variation from inbreeding can be reduced by using a large number of spawners and using approximately equal numbers of males and females.

The phenotypic variation in broodstocks should reflect the variation observed in wild populations in order to reduce the effect of inadvertent selection. The broodstock should include an array of individuals that represent the extent of variation normally observed in a population, especially with respect to timing (migration, spawning, smolting, emergence), and size (and thus correlated traits such as fecundity, egg size, age). Even if the practice is inconvenient, hatchery broodstock managers should use spawners from the entire stock. Failure to do so is likely to cause the loss of the valuable variety of traits present in the stock. Particular practices that perhaps should be avoided are selection for run timing (for example, using the earliest returns to ensure adequate egg numbers) and selection against jacks.

It is important that broodstock managers monitor the performance of the broodstock over the generations. Without a recorded history changes will not be apparent. If changes are not apparent and understood, broodstock management practices cannot adapt to changes. At the least, the broodstock manager of a hatchery stock should monitor such fitness related traits as timing of migration and maturation, size and age of spawners, egg size and egg number in spawners.

Recommendations

A. Policy

1. Abide by established 1985 genetic policy.

Alaska Department of Fish and Game, with public input, has developed a genetic policy. The policy was written to protect Alaska's valuable salmon resource. Wild stocks are the mainstay of the Alaska fishery economy; hatchery enhancement is meant to supplement but not to replace them. Hatchery programs must be carefully designed to protect wild stocks, and all

aquaculture programs, present and future, should be reviewed for compliance with the State's Genetic Policy.

2. Assume that all local populations are genetically distinct.
until more data available
Unless otherwise indicated, spatially or temporally distinct spawning aggregations should be presumed to be reproductively isolated populations.

3. Use best possible tagging strategies to monitor interactions between hatchery and wild populations and the genetic "health" of wild and enhanced populations.

Marking techniques might include coded-wire tags, otolith marking, genetic marking or other methods appropriate to the species and logistical constraints of the facility. Genetic marking would be especially valuable for monitoring introgression of hatchery stocks with natural populations. Genetic stock identification or other appropriate techniques should be used to facilitate in-season management of mixed-stock harvests.

Minimize gene flow to wild population what is risk
4. Remote releases of hatchery fish should be conducted in a manner that minimizes potential gene flow to wild populations.

Remote releases have been identified as a source of undesirable gene flow from hatchery populations to wild populations. Best available technology should be used to insure proper imprinting. Juveniles for remote releases should be held for an appropriate amount of time for imprinting at a release site possessing a freshwater source devoid of conspecifics. A remote release site, even if designed for complete mop-up fisheries, should be considered to be a de facto hatchery site (see Genetic Policy for broodstock/hatchery site guidelines).

- recognize utility of remote release as tool
- this presents risks that some genetic

B. Activities

1. Keep genetic policy current and pertinent to Alaska's resources and industry.

2. Identify genetic population structure to determine what populations are genetically distinct.

Traits examined should include life history, production, and molecular genetic. Populations should be surveyed prior to any aquacultural activity to provide a baseline for subsequent genetic monitoring. The genetic consequences of hatchery production on adjacent populations should be evaluated during phased-in expansion, and production increases should be halted at the first indication of adverse impact. Production strategies should be adjusted to eliminate any such impact.

3. Monitor wild and hatchery stocks to determine extent of straying and introgression.

Long-term monitoring of genetic traits of adjacent wild populations should accompany any aquaculture program. Again, production strategies should be adjusted to eliminate any observed straying or introgression.

4. Evaluate the homing of remote-released fish to make the practice as safe as possible.

genetic monitoring should be considered cost of doing hatchery program.

voluntary or required

hatcheries now monitor for disease - short term risk

genetic monitoring - long term risk

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DATE 2/3/92

TO: Mary

FAX NUMBER: 4928

FROM: Glenn Gray

Transmission of the following number of pages including this page 3

MESSAGE:

I called Bill Smoker and he reaffirmed that [redacted]. Mr. Smoker is chair of the resolutions committee of the Alaska Chapter of the American Fisheries Society. The committee is still accepting comments on the proposal.

of "A Tongass Treasure: The Cave Resources of Southeast Alaska," by Jim Baichtal, a geologist with the U. S. Forest Service.

Immediately following the meeting, there were tours for interested members at the fish processing facilities of Silver Lining Seafoods, the FRED hatchery at Deer Mountain and the SSRAA hatchery at Beaver Falls.

Chapter Comments on Tongass Forest Management Plan

The Alaska Chapter has sent a letter to the U. S. Forest Service in response to the Forest Service's request for public comment on the Supplement to the Draft Environmental Impact Statement (DEIS) for the Tongass National Forest Land Management Plan (TLMP). The letter was reviewed by the Environmental Concerns Committee and approved by the Executive Committee. The Chapter had previously gone on record supporting regulations requiring 100 foot wide buffer strips along fish-producing streams in areas of the Tongass that are to be logged. The Supplement to the DEIS does now include those requirements, as mandated by the Tongass Timber Reform Act. In our comments on the Supplement, the Chapter emphasized that such buffers should be considered minimums, and that habitat biologists should be granted wide discretion to extend the width of the buffer as needed to protect particularly sensitive riparian habitats and valuable fish populations. The Chapter recommended the Forest Service reject the Plan Alternative that did not use the most conservative riparian habitat management prescription.

The Chapter also commented on the inadequacy of the DEIS and the Supplement in addressing the impacts of upland uses, such as roading and logging, on spawning populations of salmon, especially pink salmon. The DEIS and Supplement acknowledge "greater risk" to populations in impacted watersheds, but assume no effect on productivity of these fish in comparing alternative forest management strategies.

[redacted] River Wild Stock Management Zone

The following draft resolution was identified at the Annual Meeting, and the membership present voted to have it publicized for informational purposes in the next issue [this one] of Oncorhynchus. **IT HAS NOT BEEN APPROVED BY THE MEMBERSHIP**; it does not represent an official position of the Chapter. Background material that was provided by the author of the resolution follows the resolution itself.

The Chapter also received a draft of the "United States Proposal for Establishing a Cooperative Yukon River Salmon Wild Stock Restoration Program." This draft was prepared by the U.S. delegates, including members of both Alaska and National agencies, to the Joint Technical Committee considering Yukon River salmon policy with respect to the U.S./Canada Salmon Treaty. The draft proposal provides insight into the current planning process to establish cooperative management policy for the Yukon. This current process anticipates two outcomes: 1) the establishment of a Regional Planning Team for the Yukon (RPT's in Alaska are representative public bodies that plan salmon enhancement and management and which have been given responsibility for designating genetic sanctuaries), and 2) participation in a joint US/Canada planning process in the Yukon River watershed.

[redacted] to this draft document, the [redacted] the policy priorities of the [redacted] membership [redacted] proposed resolution should be tabled. The following material is being presented to inform the membership about the resolution and to solicit comments on the resolution.

Particularly useful would be comments on the scope of the Chapter's recommendation.

The Yukon is home to a unique group of Pacific salmon, subarctic animals adapted to near arctic conditions. They deserve special care. Should, therefore, resource users of the Yukon be denied any enhancement of salmon production beyond the capacity of wild spawning habitat? There is of course widespread current debate of whether artificial enhancement ever can increase production over that supported by wild spawning habitat, and perhaps that is the core of the proposed resolution's author's concern.

Alaska has a long established mechanism (RPT's) for public participation in the controlled development of salmon enhancement and Alaska has strong genetic and disease policies that are applied in all salmon enhancement projects. Does the Chapter anticipate that this process will be inadequate to the difficult task of protecting the Yukon's stock diversity? Perhaps that anticipation is also at the core of the proposed resolution.

The Chapter in 1988, in a similar resolution supported establishment of genetic sanctuaries (or refuges) in which harvests but not enhancement could occur and this proposed resolution seeks establishment of a large sanctuary in the Yukon. Is the present protection offered by national parks and refuges inadequate? Will the entire Yukon have to be set aside in order to provide adequate protection?

Please send your comments to W. W. Smoker, Resolutions Committee Chair, University of Alaska Fairbanks, Juneau Center for Fisheries and Ocean Sciences, 11120 Glacier Highway, Juneau, AK 99801 (789-4441) (FFWWS@Alaska). To encourage frank discussion the Committee promises to keep confidential the identities of comment authors.

Proposed Resolution
Yukon River Wild Stock Management Zone

WHEREAS, the Yukon River is one of the largest producers of wild chum and chinook salmon in North America; and

WHEREAS, supplemental hatchery production is being considered as a means to increase harvest levels of Yukon River salmon; and

WHEREAS, increased harvest levels have a potential to severely impact the many small wild stocks included in the mixed stock and mixed species fishery; and

WHEREAS, available scientific literature suggests that hatchery produced salmon can stray and interbreed with wild stocks altering the wild gene pool, reducing stock fitness and threatening the survival of wild populations;

BE IT RESOLVED, the American Fisheries Society, Alaska Chapter, urges the governments of Canada, United States and Alaska to manage the Yukon River as a Wild Stock Management Zone and to implement the following resolutions:

1. Rebuilding of depressed wild salmon stocks should be accomplished with proper management of the resources and not

accomplished through increased hatchery production;

2. Management of the mixed stock fisheries should be governed by the least productive stock with regulations set to insure that these small stocks do not become extinct;

3. In no instance should hatcheries be used as a means to increase harvest levels;

4. As a last resort, aquaculture techniques may be necessary if a specific stock would become extinct without direct intervention.

BACKGROUND

(Statement prepared by author of the proposed resolution)

The Yukon River is one of the largest producers of wild "unenhanced" chum and chinook salmon in North America. Nearly all salmon spawning and rearing habitat remain intact. The fishery is mixed stock and mixed species in nature with commercial and subsistence harvest of salmon taking place from its mouth upstream almost 1,400 miles. The 1978-1986 average annual drainage-wide harvest was 185,000 chinook, 1,161,000 summer chum, 442,000 fall chum and 61,000 coho salmon (Alaska Department of Fish and Game, 1986). The demand placed on Yukon River chinook and fall chum salmon exceeds the capacity of wild stocks to satisfy all user groups and, consequently, several stocks have become depressed.

Supplemental hatchery production is seriously being considered by many managers, fishermen and politicians as a quick-fix means of alleviating the ever-growing demand placed upon the Yukon River salmon resource. Proposals include expansion of the Clear Hatchery near Fairbanks (Tanana River), increasing funding for artificially enhanced Canadian stocks through treaty stipulations, and developing small-scale aquaculture 4-H projects throughout U.S. waters. The necessary public involvement process has not been initiated for Yukon River enhancement projects, even though the effects may be substantial.

Available scientific literature suggests hatchery produced salmon can negatively impact wild populations by decreasing genetic diversity, reducing stock fitness and reducing effective population size. Foreign diseases can also be introduced from hatchery salmon. The salmon stocks of the Pacific Northwest should exemplify what happens when hatcheries are used to "mitigate" for declining wild salmon stocks. Some salmon stocks are currently being considered for listing under the Endangered Species Act largely due to the ineffectiveness and misuse of salmon hatcheries.

Nehlsen et al. (1991) identified the status of Pacific salmon, steelhead and cutthroat stocks in the Pacific Northwest which included 214 naturally spawning depleted stocks, 101 of which were at a high risk of extinction. A review of 18 quantitatively evaluated supplementation projects in the Pacific Northwest, British Columbia, Alaska and New England found that none had rebuilt wild runs to self-sustaining levels (Miller et al. 1990). In a comprehensive review of supplementation programs, Smith et al. (1985) concluded that supplementation should not be initiated in wild fish only streams and that populations in these streams are best enhanced by habitat protection and harvest control.

Supplemental hatchery production will only further complicate mixed stock fisheries management. Many wild stocks are relatively small which make them extremely vulnerable to overharvest in an intensive fishery. Consequently, should mainstream harvest levels increase in response to hatchery production of salmon, then small stocks risk reduction or elimination. The status of many of these stocks have never been assessed. Management of a mixed stock fishery requires protection of the weak stocks.

References

Alaska Department of Fish and Game. 1986. Annual management report, 1986, Yukon Area. Division of Commercial Fisheries, Anchorage, Alaska.

Miller, W.H., T.C. Coley, H.L Burge and T.T. Kisanuki. 1990. Analysis of salmon and steelhead supplementation: emphasis on unpublished reports and present programs. Part I in Analysis of Salmon and Steelhead Supplementation. Project 88-100, Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon.

Nehlsen, W., J.E. Williams and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho and Washington. Fisheries 16:2, American Fisheries Society, Bethesda, Maryland.

Smith, E.M., B.A. Miler, J.D. Rodgers and M.A. Buckman. 1985. Outplanting anadromous salmonids - a literature survey. Bonneville Power Administration, Project 85-68.

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Deadline for materials for the Spring issue of Oncorhynchus is March 10.

1990

22550 A
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International Symposium on Biological Interactions of Enhanced and Wild Salmonids

June 17-20, 1991

COAST BASTION INN
Nanaimo, B.C., Canada

SYMPOSIUM SECRETARY

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Hosted by the Biological Sciences Branch,
and the Salmonid Enhancement Program, of the
Department of Fisheries and Oceans, Pacific Region

International Symposium on Biological Interactions of Enhanced and Wild Salmonids

P R O G R A M

June 16 Arrival in Nanaimo

1700-2100 Registration
Coast Bastion Inn - Foyer

1900-2100 Welcoming Reception (Ballroom) - hosted by the Biological Sciences Branch (B.S.B.), and the Salmonid Enhancement Program (S.E.P.)

June 17

0900-0930 Introductions and Opening Remarks, Dr. John C. Davis, Regional Director, Science, Institute of Ocean Sciences, Sidney, B.C., Canada, and Mr. David Griggs, Director, Salmonid Enhancement Program, Vancouver, B.C., Canada

SESSION ONE - PRODUCTION TRENDS

Chairman - Dr. F. Keith Sandercock, Salmonid Enhancement Program, Vancouver, B.C., Canada

0930-1015 Khorevin, L.D., F.N. Rukhlov, and A.P. Shershnev. TINRO Sakhalin Region, USSR. Abundance dynamics of mixed (natural and enhanced) origin salmon of Sakhalin-Kurile area.

1015-1100 Kaeriyama, M. Hokkaido Salmon Hatchery, Fisheries Agency of Japan, Sapporo, Japan. Production trends of salmon enhancement in Japan.

1100-1130 Break

1130-1215 Peltz, L., et al. Alaska Department of Fish and Game, Cordova, Alaska, U.S.A. [Presented by D.M. Eggers]. Trends in abundance of hatchery and wild stocks of pink salmon (Oncorhynchus gorbuscha) in Kodiak Island, lower Cook Inlet, and Prince William Sound, Alaska.

1215-1330 Lunch

1330-1415 Steer, G., et al. Department of Fisheries and Oceans, Vancouver, B.C., Canada. Trends in biological characteristics and survival rates of wild and enhanced salmonids in British Columbia.

1415-1500 Hilborn, R., R. Francis, and S. Hare. Fisheries Research Institute, University of Washington, Seattle, Washington, U.S.A. Hatchery and wild fish production on the Columbia River.

1500-1530 Break

1530-1615 Whelan, K.F., and P. McGinnity. The Salmon Research Agency of Ireland Incorporated, County Mayo, Ireland. A comparative biological and genetic profile of wild and ranched Atlantic salmon (Salmo salar L.) stocks from the Burrishoole system, Co. Mayo, Western Ireland.

1615-1700 Karlsson, L., T. Eriksson, and C. Eriksson. Swedish Salmon Research Institute, Älvkarleby, Sweden. Production trends in reared Swedish stocks of Baltic salmon.

1845-2100 **POSTER SESSION RECEPTION** (Ballroom) - hosted by the Oak Bay Marine Group, April Point Lodge, Province of British Columbia, Rhys Davis Ltd., B.C. Packers Ltd., and Canadian Fishing Company.

June 18

SESSION TWO - GENETIC CONCERNS

Chairman - Ms. Ruth Withler, Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada

0830-0915 Allendorf, F.W. University of Montana, Missoula, Montana, U.S.A. Effects of genetic changes in enhanced stocks on productivity of wild and enhanced salmonid populations.

0915-0945 Crandell, P.A. University Alaska Fairbanks, Juneau, Alaska, U.S.A. Genetics of domestic California rainbow trout (Oncorhynchus mykiss): implications for wild stocks.

0945-1015 Chebanov, N.A. TINRO, Kamchatka Region, USSR. Experimental assessment of genetic aberrations in hatchery salmon and the possibilities of their reduction.

1015-1045 Break

1045-1115 Gharrett, A.J., et al. University of Alaska Fairbanks, Juneau, Alaska, U.S.A. Use of a genetic marker to examine genetic interaction among subpopulations of pink salmon (Oncorhynchus gorbuscha).

1115-1145 Zhivotovsky, L.A. National Academy of Sciences, Moscow, USSR. Population dynamics of pink salmon.

1145-1330 Lunch

Chairman - Dr. A. J. (Tony) Gharrett, University of Alaska Fairbanks, Juneau, Alaska, U.S.A.

1330-1400 Skaala, Ø., K.E. Jørstad, and R. Borgstrøm. Institute of Marine Research, Bergen, Norway. Genetic impact on wild populations from fish farming: experiments with genetically tagged brown trout (Salmo trutta L.).

1400-1430 Smoker, W.W., A.J. Gharrett, and M.S. Stekoll. University of Alaska Fairbanks, Juneau, Alaska, U.S.A. Genetic variation in seasonal timing of anadromous migration in a population of pink salmon.

1430-1500 Kawamura, H. Makkari Branch of Hokkaido Fish Hatchery, Hokkaido, Japan. Stock enhancement of masu salmon (Oncorhynchus masou) with hatchery-reared fish and difference in timing of smolting between hatchery and wild populations in Hokkaido, Japan.

1500-1530 Break

1530-1600 Leary, R.F., and F.W. Allendorf. University of Montana, Missoula, Montana, U.S.A. Use of meristic variation to monitor the health of salmonid fish populations.

1600-1630 Gritsenko, O.F., and A.A. Kovtun. VNIRO, Moscow, USSR. Interaction between wild and reared parts of chum salmon populations from the Tym' River.

1830-2200 **BANQUET** (Ballroom) - Invited speaker: Mr. Ike Baart, Vice-President, Export Sales, British Columbia Packers Ltd., Vancouver, B.C., Canada. Marketing aspects of salmon production.

June 19

SESSION THREE - FACTORS AFFECTING FRESHWATER AND MARINE PRODUCTION

Chairman - Dr. Doug M. Eggers, Director of Research, Commercial Fisheries Division, Alaska Department of Fish and Game, Juneau, Alaska, U.S.A.

0900-0945 Kitchell, J.F. Center for Limnology, University of Wisconsin, Madison, Wisconsin, U.S.A. Salmon in the Great Lakes: a compromised miracle.

0945-1015 Karpenko, V.I. TINRO, Kamchatka Region, Petropavlovsk, Kamchatka, USSR. The role of early marine life in forming Pacific salmon production.

1015-1045 Beamish, R.J., and B.L. Thomson. Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada. Survival of hatchery-reared salmon in the Strait of Georgia.

1045-1115 Break

1115-1145 Wood, C., et al. Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada. Testing for ecological interactions between wild and hatchery-reared salmonids as an explanation for declining smolt-to-adult survival in sockeye salmon (Oncorhynchus nerka) populations of Barkley Sound, Vancouver Island.

1145-1215 M^{c}Allister, C.D., and C.D. Levings. Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada. Evidence of habitat limitations for hatchery and wild chinook salmon (Oncorhynchus tschawytscha) in two British Columbia estuaries.

1215-1330 Lunch

Chairman - Dr. Blair Holtby, Department of Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station, Nanaimo, B.C., Canada

1330-1400 Beall, E., and M. Héland. INRA, Unite Ecologie des Poissons, Station d'Hydobiologie, Saint-Pee-sur-Nivelle, France. The influence of introduced coho salmon (Oncorhynchus kisutch) juveniles on the survival, growth, distribution, and production of Atlantic salmon (Salmo salar) fry and parr.

1400-1430 Seiler, D., et al. Washington Department of Fisheries, Olympia, Washington, U.S.A. Supplementation of wild coho salmon (Oncorhynchus kisutch) with hatchery-produced fry in Washington coastal streams.

1430-1500 Cramer, S.P. S. P. Cramer & Associates, Fisheries Consultants, Corvallis, Oregon, U.S.A. Dynamics of the decline in wild coho (Oncorhynchus kisutch) populations in the lower Columbia River.

1500-1530 Break

1530-1600 Labelle, M., C.J. Walters, and B.E. Riddell. University of British Columbia, Vancouver, B.C., Canada. [Presented by C. Walters]. Ocean survival and exploitation patterns of hatchery and wild stocks of coho salmon (Oncorhynchus kisutch) from southeast Vancouver Island, British Columbia.

1600-1630 Francis, R.C., and R.D. Brodeur. Fisheries Research Institute, University of Washington, Seattle, Washington, U.S.A. Production and management of coho salmon (Oncorhynchus kisutch): a simulation model incorporating environmental variability.

1700-2200 **TOUR** - Choice of tour to Big Qualicum River Project or Robertson Creek Hatchery/Somass River. (Dinner not included in registration.)

June 20

SESSION THREE - (continued)
FACTORS AFFECTING FRESHWATER AND MARINE PRODUCTION

Chairman - Dr. Robert C. Francis, Fisheries Research Institute, University of Washington, Seattle, Washington, U.S.A.

0900-0930 Ward, B.R., F.A. Slaney, and A.F. Tautz. Ministry of Fisheries, Province of British Columbia, University of B.C., Vancouver, B.C., Canada. Differential survival and synchronous return from the sea in Keogh River wild and hatchery steelhead (Oncorhynchus mykiss).

0930-1000 Leskelä, A., et al. Merenkurkku Fisheries Research Station, Vaada, Finland. Variations in the relative year-class strength and growth of anadromous whitefish (Coregonus lavaretus s. str. L.) in the rivers flowing into the Gulf of Bothnia.

1000-1030 Evans, D.O. Ontario Ministry of Natural Resources, Fisheries Branch, Maple, Ontario, Canada. Factors affecting angling yields of wild, self-sustaining, and hatchery-supplemented stocks of lake trout, Salvelinus namaycush, in eastern Canada.

1030-1100 Break

1100-1130 Hayashizaki, K., and I. Hitoshi. School of Fisheries Science, Kitasako University, Japan. Size decrease of chum salmon, Oncorhynchus keta, in Tohoku districts, Japan.

1130-1200 Koenings, J.P., et al. Alaska Department of Fish and Game, Soldotna, Alaska, U.S.A. [Presented by G. Kyle]. Collapsed populations and delayed recovery of zooplankton in response to intense juvenile sockeye salmon (Oncorhynchus nerka) foraging.

1200-1330 Lunch

June 20

SESSION FOUR - FISHERIES MANAGEMENT

Chairman - Mr. Paul E. Sprout, Division Manager, South Coast Division, Fisheries Branch, Department of Fisheries and Oceans, Nanaimo, B.C., Canada.

1330-1415 Geiger, H.J., et al. Department of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska, U.S.A. The management of the Alaskan salmon hatchery commercial harvest.

1415-1500 Riddell, B.E., P.E. Sprout, and A. Cass. Department of Fisheries and Oceans, Nanaimo, B.C., Canada. Managing wild and enhanced salmonids: a review of three British Columbia fisheries.

1500-1530 Coffee

1530-1615 Lichatowich, J.A., and J.W. Nicholas. Jamestown Klallam Tribe, Sequim, Washington, U.S.A. The use of hatcheries in the management of Oregon's chinook (Oncorhychus tschawytscha) and coho (O. kisutch) salmon stocks: case histories and general observations.

1615 Chairmen's Concluding Comments

Concluding Remarks - B. E. Riddell, Organizing Committee Chairman

Production trends of salmon enhancement in Japan

Masahide Kaeriyama

Hokkaido Salmon Hatchery
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Japan

Most Pacific salmon stocks in Japan derive from hatchery production except for some natural spawning populations of masu and kokanee salmon. The abundance of chum and pink salmon increased from 5 and 1.2 million individuals in the 1960s to 50 and 3.8 million individuals in the 1980s, respectively. Success of the enhancement program for chum and pink salmon in Japan has resulted from increases in the return rate and the numbers of juvenile released. With an exponential increase of the population size, however, decrease in size and increase in average age have been observed among adult chum salmon returning to Japan. These phenomena suggest that there has been a density-dependent reduction of growth of individuals within Japanese chum salmon populations. However, there is little evidence that the survival of chum salmon has declined. In addition, fears have been expressed concerning effects of hatchery production on the genetic variability of chum and pink salmon. These fears may be supported by the following observations: (1) reduction in the proportion of effective number of breeding to total number of returning chum salmon, (2) a decrease in late running individuals of chum and odd-year pink salmon, (3) reduction of variation in the timing and duration of maturation of individual fish. Future objectives of the salmon enhancement program are summarized as follows: (1) ecological stock management based on the systematic planned production of salmon populations within their carrying capacity in the North Pacific Ocean, (2) genetic preservation of original populations and genetic stock management, and (3) supply of better quality salmon as food for consumers by increased production programs of sockeye and masu salmon.

Hatchery and wild fish production on the Columbia River

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Because of extensive hydroelectric development, the Columbia River has been the site of the most intensive hatchery program for Pacific salmon in North America. In this paper we review the history of hatchery releases on the Columbia, and, to the extent possible, document the production of adult fish from these hatchery releases. The hatchery programs have not been successful at mitigating for the loss of natural runs; returns of adult salmon to the Columbia are far below what they were prior to the development of the hydroelectric system. Many hatcheries have failed to produce adult fish, and constitute a net drain on the system by using natural spawners as an egg source. In addition, comparative studies suggest that wild fish normally show much higher survivals than hatchery fish.

We conclude that the attempt to mitigate for losses on the Columbia River by hatcheries has failed, and suggest that the following actions be taken to make the hatchery program more successful. First, hatchery managers should receive financial incentives for production of adult fish from their facilities, rather than for release of juvenile fish. Second, hatcheries should be required to periodically prove their effectiveness through a licensing hearing, and hatcheries that have failed to make a real contribution to the adult return should be closed.

Effects of genetic changes in enhanced stocks on productivity of wild and enhanced salmonid populations

F.W. Allendorf

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Programs designed to increase productivity through artificial enhancement generally increase productivity in the immediate future; however, such activities may affect genetic resources adversely and decrease sustainable productivity over longer periods of time. Genetic changes are expected to occur in enhanced stocks because of genetic drift, inadvertent selection, and purposeful selection. A large body of empirical data indicates that such genetic changes are common in salmonid stocks. Determining the genetic effects of enhancement programs on wild populations is much more difficult. Nevertheless, there is growing evidence that enhancement programs often have affected wild populations by causing the loss of local adaptations and by increasing natural patterns of genetic exchange among subpopulations (i.e., increasing gene flow). The genetic diversity present in wild populations of salmonids is an invaluable and irreplaceable resource.

Dynamics of the decline in wild coho (Oncorhynchus kisutch) populations in the lower Columbia River

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Corvallis, Oregon 97330
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Populations of wild coho salmon spawning in tributaries of the Columbia River below Bonneville Dam (km 235) declined precipitously during 1971-73 and have remained at low levels since. Abundance of coho returning to 15 hatcheries within this lower Columbia area remained stable through these years. Although abundance declined simultaneously in wild populations throughout the sub-basin, data on spawning time, ocean distribution, and fecundity clearly indicate stock differentiation. Time of peak spawning ranges from late October to mid-February. Experiments with brood selection of lower Columbia coho have demonstrated time of migration and time of spawning are highly heritable and correlated. Hatchery stocks now enter the Columbia River and spawn 4-8 weeks earlier than the natal populations from which they were derived. Spawning time of wild coho in the Clackamas River, a tributary, has shifted 2 months later since 1970, apparently in response to selection by high harvest rates in the Columbia River during the historical peak time of river entry. Evidence is presented that selection for time of river entry and time of spawning is continuing.

The sharp decline in abundance of coho during 1971-73 was coincident with a sharp increase in harvest rates in the river and ocean. Harvest simulations demonstrate that present harvest rates will drive wild populations to extinction. Outplanting of poorly adapted hatchery coho probably aggravated the decline of wild populations.

Managing wild and enhanced salmonids: a review of three British Columbia fisheries

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Intermingling of salmonids from enhancement programs with wild salmonids complicates the already formidable task of managing Pacific salmon fisheries. In this paper we document catch trends and harvest management issues associated with enhancement in three major salmon fisheries in British Columbia. The enhancement programs include: (1) the Babine Lake sockeye spawning channels developed to increase production to the Skeena River sockeye fishery; (2) Robertson Creek Hatchery, Canada's largest chinook hatchery, developed to increase catch in ocean troll fisheries and which now supports important terminal fisheries in Barkley sound and, (3) the complex of hatcheries developed in the Strait of Georgia to increase the catch of chinook and coho salmon in the Strait. Enhancement has exacerbated mixed-stock and mixed-species problems in salmon management but has also resulted in new or augmented fishing opportunities. However, for enhancement to be integrated with management of wild stocks requires explicit production objectives and harvest management plans. Experiences in managing these fisheries are compared and recommended roles for enhancement are discussed. Further, we suggest that more effort be directed at how harvest management policies can be implemented that provide for a balanced approach in the use of enhancement.

The use of hatcheries in the management of Oregon's chinook (*Oncorhynchus tschawytscha*) and coho (*O. kisutch*) salmon stocks: case histories and general observations

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U.S.A.

Artificial propagation has been a major tool in the management of Oregon's chinook and coho salmon stocks for over 100 years. However, the role of hatcheries in the management of coastal stocks of the two species has differed. Coastal stocks of chinook salmon have been managed primarily for natural production whereas coastal stocks of coho salmon have been managed primarily for hatchery production. An overview and comparison of the two programs is presented. Specific case histories that provide greater understanding of the use of artificial propagation in fisheries management are discussed. The lessons obtained from Oregon's use of artificial propagation over the past century are summarized.

November 14, 1991 Ted Cooney

Ocean Carrying Capacity - Session 1 Review

Five presentations reviewed several different aspects of the issue of carrying capacity as it pertains to salmon production in the north Pacific Ocean. A theoretical food-web model was used to estimate present levels of fry (1.2 billion combined wild and hatchery) feeding demand on naturally occurring zooplankton stocks in Prince William Sound. Estimates of food demand driven by juvenile growth rates of 3 - 5 % body weight per day and adjusted for early ocean fry mortality, suggested minimal impact (< 10%) on total annual zooplankton production. Uncertainties associated with interpreting these model results included questions about the residence time of juveniles in the Sound, and the percentage of the region actually used for feeding purposes. Additional information about relative forage stock abundance in shelf and coastal environments in Lower Cook Inlet and near Kodiak Island was presented to suggest the 'uniqueness' of Prince William Sound as a juvenile salmon foraging habitat. Communication with the 'open' Gulf of Alaska and the depth of the Sound (to 800 meters) interact to host much larger zooplankton stocks than found elsewhere in southcentral Alaska.

Density-dependent growth patterns were described from Japanese hatchery-released chum salmon returning to the Iwate Prefecture (Honshu). Over the past two decades the production of chum salmon in Japan has increased from 5.8 to 50 million adults. During this period, several dramatic changes have been documented. Adult body size and weight have declined, while the mean age of adults has increased slightly. For (ocean?) age 4 (0.3) fish, growth reduction (stunting) determined from scale analyses was most pronounced during the first year of ocean residence . A general decline in the number of eggs per female also accompanied the overall size of adults, as did the condition factor. These measurable changes were attributed to density

dependent growth limitations associated with increasing numbers of hatchery releases.

Density-dependent growth was also described for Bristol Bay sockeye salmon form 1959 - 1991. The extremely small size of returning fish (marine age and sex) in 1990 and 1991 prompted a re-analysis of density-dependent growth accounting for red and chum salmon originating from other areas. The inclusion of fish from outside Bristol Bay did not improve the correlation between numbers of Bristol Bay salmon and mean size in a run. Although sea surface temperatures during winter improved the overall multiple correlation, the small-sized 1990 and 1991 sockeye salmon remained as outliers. It was concluded that the greatest effects of density-dependent growth occur during the last winter/spring of ocean residence in schools of maturing fish near the Alaska Peninsula. No explanation was provided for the anomalous 1990 and 1991 small-sized sockeye salmon.

Historical hatchery practices in Washington and Oregon were discussed to illustrate major mistakes associated with early attempts at large-scale salmon stock rehabilitation programs in the Columbia River. While the intent was meritorious, results were generally disastrous, giving rise to ever increasing problems over time. Coho salmon production declines, blamed on ocean growth conditions, were later attributed to poor freshwater survival and diseases. Precocious returns following external?? freshwater rearing led to greatly reduced reproductive potential. Increased fishing pressure on hatchery stocks eliminated already weakened wild populations. Little or no attention was paid to artificially induced behavioral changes in hatchery stocks including feeding 'niches' and smolting times. These and many other unfortunate results of 'learning by doing' have cast serious doubts on artificial propagation as a mitigation tool. Fortunately, the results of these dubious or otherwise misguided practices are a matter of record. There is no reason that the lessons of Washington and Oregon need to be relearned in Alaska. In this case, 'hindsight' is available in the present and must be

used to prevent the kinds of mistakes that have characterized hatchery and management practices elsewhere.

The session concluded by reviewing some of the broader aspects of the carrying capacity phenomenon in the North Pacific Ocean. A discussion of historical salmonid stock data and oceanographic factors (conditions) demonstrated relationships between forage stock abundance and fish weight, between ocean survival and ocean growth, and between growth conditions and ocean temperature. Since 95% of the growth of salmon occurs in the sea, it is not surprising that variable ocean conditions result in measurable changes in salmon growth and survival. This understanding is still in its infancy, although advances in oceanography and fisheries science are adding new knowledge at an increasing rate. The oceanic environment can no longer be considered a black box.

There is a carrying capacity for ocean. What it is is not known.
Density dependency
Problem w/ smaller size - growth conditions
fecundity
marketing

why small size - ecosystem dynamics
near shore
shelf bed
open ocean

PWS data in litigation.
* when this data forthcoming, convene another workshop on that
- where does density dependent growth occur
- need for quantitative effects of predation + competitors
local predator watch
Atka pollock may be major predator (Gulf)
- ~~PWS~~ open ocean vs. local areas.
PWS - wild stocks not at highest abundance, but

New technologies available – need to use them
~~Satellite~~, oceanographic buoys, acoustics (sonics)

natural scope of open ocean –
long term – limit on No. Pacific production?

other phenomena – sea lions and fur seals ↓
monitor other measures of carrying capacity

productivity of ocean not constant, are we headed to natural decline?

inverse relationship – ocean temp. & wild reproduction

no strong evidence that we have reached carrying capacity for ocean for salmon, but perhaps have on local areas.
– how small is too small – crucial question.
– early & late are target areas.
–
– when get too small – might start making parks nature as 3 yr breakdown in age structure could affect future productivity etc.

B Bay sockeye, Quesnino, all pink stocks smaller this year.

no evidence now, but should be cautious about future.

November 14, 1991

Don Amend

Can wild and enhanced coho stocks co-exist in S.E. Alaska?

Background

The Alaska legislative mandate during the development of statutes and regulations for the Alaska enhancement program was to manage for the natural stocks while enhancing salmon to supplement natural production. The enhancement of coho salmon in S.E. Alaska stated in the mid-1970's by the FRED division and the private non-profit operations started in the early 1980's. These programs have now matured and production has stabilized.

The average annual harvest of coho salmon from 1980 through 1988 was 1.71 million. The average harvest of enhanced coho from 1986 through 1990 was 8.1 percent of the total harvest, but the average in the future, based on current production levels, is expected to average about 16 percent.

Coho in S.E. Alaska are harvested primarily by trollers but significant harvest occurs by the drift gillnet and seine fleets as a by-catch during the conduct of traditional fisheries. Although some coho are harvested from Canadian systems, most are produced from S.E. Alaska systems. Because most of the coho harvested in S.E. Alaska are from natural production, it is important to maintain the wild coho stocks.

Enhancement Strategy

The enhancement strategy in S.E. Alaska follows three basic

courses: (1) release from freshwater raceways as smolts into adjacent rivers, (2) release from marine net pens as smolts at remote locations following an imprinting period, and (3) release fed fry into non-anadromous lake systems and the fish immigrate after rearing and smolting in the lake. Typically, broodstock were secured from local wild stocks and the fry reared in hatcheries located on non-anadromous systems which are not near natural producing stocks. Fish released as smolts are typically reared about 18 months in a hatchery, and the fish return after about 18 months at sea. Fish released as fed fry are reared to about a 1 gm size in the hatchery, but they complete the remainder of their life cycle similar to wild coho.

Threats and/or Concerns

There are both intra-species and inter-species concerns. The intra-species concerns include wild stock interactions due to straying or competition and management implications. Inter-species concerns primarily involve predation.

There have been no documented negative impacts of enhanced coho on wild coho in Alaska. Hatcheries in S.E. Alaska are located on non-anadromous systems, therefore, the smolts do not compete with wild stocks in the freshwater phase after being released. Coho imprint well to the site where they are released and there have been no documented straying problems. Consequently, there have been no genetic problems regarding inbreeding at hatchery coho and wild coho. Potential exists for future problems if hatchery stocks become inbred and significant

straying occurs. This should require continued monitoring. Also, research should better define minimum conditions for imprinting for remote release programs. Enhancement practices should continue to follow policies that would minimize inbreeding or increased straying.

The recent past average of 8 percent enhanced coho in the harvest has not been a management problem. Even with production capacity at a maximum, the forecast is to average 16 percent of the harvest. Also, all coho releases include a coded wire tagging program. This allows managers to account for the hatchery contribution to the harvest. Due to the low percentage of enhanced coho in the total harvest, there should be no future management concern. However, the coded wire or marking programs should continue to avoid potential problems of local abundance near hatchery sites.

The inter-species concerns are primarily coho smolts predating on pink fry and to a lesser extent on chum fry. The scientific literature well documents that coho smolts will eat pink fry and in preference to chum fry. In areas where there is a high abundance of coho smolts, the potential exists for the coho to have a significant impact on pink salmon populations. Whether coho are a limiting factor overall to pink salmon abundance is a much broader question which can only be answered by resolving the overall predator-prey relationship among all predators. Because coho abundance cycles coincide when pink abundance appears to argue against a positive correlation of coho limiting pink

abundance. However, this does not resolve the concern of high coho abundance near hatcheries where wild pink fry are migrating.

Several studies in S.E. Alaska have been conducted to answer concerns about high abundance of coho predating on pink fry. The results were inconclusive. Pink fry were on occasion found in the stomach of coho fry, but the magnitude of the problem could not be properly answered. Early life histories of pink fry showed that they typically spend a short time in the inter-estuaries and 90 percent of the pink fry have migrated toward offshore by late May. In order to minimize the impact period, hatchery released of coho smolts have been delayed to after June 1st. Although this is not considered to be the optimum release time for coho (mid-May would be better), satisfactory survival rates for coho have occurred. This appears to be a satisfactory compromise in order to reduce the concerns of high abundance of hatchery coho negatively impacting pink populations.

Conclusions and Recommendations

Enhanced coho stocks can co-exist with wild coho stocks as long as current policies and practices are maintained. Coho hatcheries should not be located on anadromous systems or near major coho producing systems. Hatchery practices should be followed to minimize inbreeding and practices which would increase straying should be avoided. The current level of production should not be a management concern but tagging programs should be maintained to resolve concerns of local abundance. Research is needed to better define the conditions for

optimum imprinting and the predator-prey relationship between coho smolts and pink fry needs to be better defined. The coho enhancement program in S.E. Alaska appears to be meeting the original legislative intent of supplementing the harvest of coho salmon but not negatively impacting wild stocks.

Tony Gharrett –
N SE - don't use local stocks, concerned @ this.
— make planted in Auke Bay. (F&G)
seems publish since there are other options.

Jim Seeb objects –

hatchery programs - ~~past~~ + future should be reviewed for compliance w/ state genetic policy.

November 14, 1991

Don Bailey -

Harvest Management of Mixed Stocks of Enhanced and Wild Pink and Chum Salmon

B.C. + other areas.

Ample evidence exists in Pacific Salmon harvest management that harvesting has occurred above their sustainable capacity. Hatchery production in many cases has been a response to low production caused by overharvesting. Evidence also exists that wild stocks can be harvested beyond their sustainable capacity when mixed with the more abundant and more productive enhanced stocks.

Depending on their productivity wild pink and chum stocks may be able to sustain harvest rates of 50 - 70% while enhanced stocks should be able to sustain harvest rates of 85-95%. In British Columbia where enhanced and wild stocks co-exist, exploitation level is based on the lower wild stock productivity and often on the weakest stock. Additional harvest of enhanced stocks is then carried out in terminal harvest areas. This is the procedure used to manage the South Coast of B.C. chum stocks passing through Johnstone Strait.

Data on the productivity of wild stocks is important both annually and during the fishing season in order to adjust harvest to meet fixed escapement goals. In the above example pre-season estimates via tests fisheries and catch sampling for marked enhanced stocks are critical for management to fixed escapement goals. Careful management is especially critical when productivity is low. Tom Royer (pers. comm.) has shown that Gulf of Alaska air temperatures are related to pink productivity. This data would indicate the future pink productivity may be lower. Changes in stream flows from watershed harvesting are also known to seriously reduce freshwater productivity of wild pink and chum stocks. Forest harvesting in Prince William Sound and lower

marine survivals for all regions in Alaska has the potential to result in wide variability in wild pink and chum productivity.

In order to maintain or increase wild pink and chum populations while maintaining or increasing enhanced production and maximizing its harvest the following recommendations should be considered:

1. Marking of enhanced and wild pink and chum stocks (both juvenile and adult) could and should be used to design a harvest strategy to maximize harvest of enhanced stocks in mixed wild and enhanced areas while meeting escapement goals for wild stocks. Utilize this data in-season and post-season to estimate wild and enhanced components of the catch. Research into mass marking of juvenile salmonids should be funded.

2. Institute test fisheries in various locations (catch to be used to pay for charter) throughout the fishing areas to evaluate their use in wild escapement management. Sample catches for marks. These charters could also be used for adult tagging for timing and migration studies.

3. Study the freshwater productivity of wild stocks by estimating egg deposition and fry output in index streams. This is especially important if escapement goals are increased to determine if increased escapement results in higher fry output. This should also be carried out in streams pre and post logging.

4. Evaluate the effect of forest harvesting on egg-to-fry survival and spawning habitat capacity.

5. Consider increasing the escapement goal to maximize wild productivity.

6. Evaluate the timing and migration of wild stocks and use stocks which will minimize wild and enhanced mixed fishery interception.

7. Evaluate future enhancement for site location and stocks selected to minimize wild stock interception. Manageability should be a major criteria in the permission process.

8. Hold a small workshop of pink and chum management biologists from Alaska, B.C. and Washington to make recommendations for the management of enhanced and wild pink and chum stocks in Prince William Sound and South East Alaska.

no test fisheries in PWS

Wayne Donaldson

(1)

Initially drafted by William R. Heard, November 15, 1991 as part of a team effort addressing a variety of questions regarding different issues and species of enhanced and wild salmon in Alaska.

CAN ABUNDANT WILD AND ENHANCED STOCKS OF CHINOOK SALMON CO-EXIST IN ALASKA ?

This question is an outgrowth of the workshop held in Cordova Alaska, November 10-15, 1991 on the " Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska".

Chinook are the least abundant salmon in Alaska but are among the most highly prized and are often at the center of controversial fishery issues. Coastwide declines in the chinook wild stocks, especially in Washington, Oregon and British Columbia along with mixed stock ocean-troll fisheries in both countries were among the major factors leading to the Pacific Salmon Treaty between Canada and the United States.

One reason for the focus on chinook in the treaty was oceanic migration patterns of many stocks that migrate in a northwesterly direction along the U.S. and British Columbia coastlines. Many stocks of chinook become vulnerable to distant area fisheries. The troll fishery in Southeast Alaska was especially important because it caught large numbers of non-Alaska chinook originating from southerly stocks. Among other

(2)

things, the treaty called for limiting such interceptions of chinook between countries and states and for initiating a coordinated rebuilding program of depressed stocks along the coast. Other treaty provisions included a limit quota on numbers of chinook that could be caught in certain fisheries and an option for developing new stocks or groups of enhanced fish that could be harvested by the country or state of origin in addition to fish counted under the quota.

Chinook salmon hatcheries and significant related enhancement programs in southeastern Alaska have increased from two in 1976 to fifteen in 1990. New hatchery add-on provisions of the treaty was a major incentive for much of this development and the basic goal of this effort was to provide more chinook of local origin for Southeast Alaska fisheries. The primary targeted user groups for chinook salmon in this region are the commercial troll and marine recreational troll fisheries.

Most hatcheries in the region were developed with principles to have minimal impacts of hatchery fish on endemic wild stocks of chinook. Alaska Fish Genetic and Pathology Policy statements were important guidelines for selecting chinook hatchery sites, brood stocks, and enhancement practices. Unlike chinook hatcheries in many other regions, none were built on extant wild chinook streams. Most are located on islands 50 km to 200 km distant from wild stocks that are, with one exception on the mainland. Four primary hatchery stocks, derived from regional wild stocks, are in use in different parts of Southeast Alaska. Three other stocks have been involved in supplemental

(3)

enhancement of their depressed natal runs. Chinook brood stock selection for use in hatcheries and other enhancement efforts in this region is important because of differences in ocean migration patterns that result in different fishery contribution potentials for target fisheries. Upriver stocks from larger transboundry rivers (Taku, Stikine, Alsek) tend to have longer more distant ocean migrations than stocks from shorter coastal streams. Movements of eggs between hatcheries is carefully regulated based on stock, disease history and location of hatchery.

A formal interagency chinook plan for the region, with an annual annex update, provides oversite guidance on hatchery and other chinook enhancement activity within the region. The Chinook Plan Team and Plan Annex also serves as an annual monitor of individual hatchery broods relative to stock performance, fishery contributions and marine survival.

Production from both hatchery and wild stocks of chinook salmon in southeastern Alaska has steadily increased in recent years. Regional hatchery contributions to Southeast fisheries have grown from an average annual catch of about 5000 fish (1980-1985) to an actual estimated catch of 79,546 fish in 1991. After pre-treaty hatchery fish and risk factor adjustments are made, the hatchery add-on allowance for 1991 becomes 65,546 fish. One long term goal of enhancement in Southeast Alaska is to provide 100,000 add-on chinook to the commercial troll fishery. Total estimated escapements of wild chinook stocks in the region have doubled from an average of 43% of target goals (1975-1980) to 84%

(4)

(1986-1990). Target escapement goals for several wild chinook stocks within the region are increasing as better knowledge of spawner distributions within river systems becomes available.

In view of the general increases in both hatchery and wild chinook production in southeast Alaska and taking into account the conservative approaches used in development of the chinook enhancement program, there does not appear to be major problem areas of adverse hatchery stock- wild stock interactions in this region. The only known possible exception involves small numbers of adult hatchery chinook recovered in non-natal areas. The majority of these known chinook strays have been recovered from areas without natural chinook runs, although a few hatchery fish have been found in some wild chinook streams. There is some concern for the specific stock presently used for hatchery and enhancement activity in the greater Juneau area because of the proximity of the Taku River and the possibility of hatchery strays into that system. Steps are in progress to use a more suitable hatchery stock in this area. In other regions of Alaska where there are chinook hatchery and enhancement activities, including Cook Inlet, there also are no known major adverse enhanced stock-wild stock interactions.

* Chinook program considered exemplary

INTERACTIONS BETWEEN WILD AND CULTURED SALMON IN NORWAY AND SWEDEN.

Norway Sweden
Tor G. Heggberget Torleif Eriksson

Atlantic salmon smoltify and leave freshwater at sizes between 12 and 17 cm. The smolt age vary between 1 and 6 years, depending on growth conditions during the presmolt freshwater period. The salmon return to freshwater to spawn after 1, 2, 3(4) years, at size from 1 to 25 kg.

Some significant life history variations between stocks exist. Examples of variations between stocks are: timing of spawning, timing of emergency of fry, timing of smolt migration, timing of return migration and age and size at maturity. Atlantic salmon in Norway are genetically distinct from the Baltic salmon.

NORWAY

In Norway there are three main sources of cultured fish; 1)Presmolt salmon released for general enhancement of stocks, 2)Ocean ranching - smolts released to compensate negative effects due to hydropower development and ocean ranching along the coast, 3)Escapees from pen farms along the coast.

There are about 500 streams with natural stocks of salmon in Norway. The production of farmed salmon in Norway was about 150 000 tonnes in 1991, while the natural production was about 2000 tonnes.

Problems:

- Due to pen farming activities a great number of farmed

salmon have escaped and are now mixing with the wild stocks.

- Proportions of cultured fish in spawning populations have increased during the last decape, and now exeed 80% of the total number of spawners in some streams.
- Parasites and diseases introduced with import of smolts from other countries have been transferred to wild stocks with some dramatic effects. High mortality of wild salmon have occured both due to the parasitic monogean Gyrodactylus and due to furunculosis.
- Ecological interactions, for instance competition during spawning and presmolt stages between wild and cultured fish have been observed.
- Genetic effects, interbreeding, may result in erosion of local adaptations in wild stocks of Atlantic salmon in Norwegian streams.
- Ocean ranching increase fishing pressure on wild stocks.

Negative effects of interactions between cultured and wild fish are tried to be reduced by:

- Convert from pen farming to land based salmon farming.
- Minimizing numbers of strayers from ocean ranching to wild stocks.
- Releases in connection to rivers (not directly in the sea).
- Harvest of ocean ranched fishapart from wild stocks.
- Releases away from important salmon streams.
- Locally/regionally based salmonid aquaculture. No transportation of live fish material between regions.

- Effective and intensive health control of release material.

SWEDEN

The Baltic stocks of Atlantic salmon have been subjected to impact of human exploitation for many centuries. At the end of 19th century salmon spawned in 60-70 rivers in the Baltic. From 1940 onwards many of the large salmon rivers were dammed and destroyed as spawning habitats.

To compensate for the losses hatcheries were established at the rivers used for hydroelectric power production.

Problems:

- Most natural populations have disappeared due to human activities in the rivers.
- Today between 80 and 90% of the catches in the fishery have a hatchery origin.
- The catches are dominated (80-90%) of off-shore catches on mixed stocks and represent a high exploitation rate on wild stocks.
- Wild stocks are unable to cope with the present exploitation rate while the reared stocks can due to high egg-to-smolt survival in the hatcheries. Thus only about 20-25% of the production potential in the natural rivers are actually produced today.
- Management plans are proposed including a reduction of the off-shore fishery.

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31 October 1991

The Honorable Senator R.I. Eliason
Alaska State Legislature
P.O.Box V (MS 3100)
Juneau, Alaska 99811

Dear Senator Eliason:

The workshop on the "Biological Interactions of Natural and Enhanced Stocks of Salmon" will soon start. I want to thank you for making travel funds available, which have enabled us to invite a large number of experts. Enclosed is a copy of the Agenda which is final except for a few minor changes or additions. Also enclosed is a copy of the final Prospectus distributed to the participants.

I shall keep you informed on our progress.

Sincerely yours,

Ole A. Mathisen

Ole A. Mathisen
Professor of Fisheries

TENTATIVE AGENDA
Workshop on the
"Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska"

Saturday, November 9

Participants arrive during the day.

6:00-7:30 pm Welcoming reception, at the Powder House (transportation provided).

All the plenary meetings are held in the Masonic Hall (located at the north end of First Street). The daily schedule is as follows:

7:45 - 8:30 a.m.	Continental Breakfast	(at the Masonic Hall)
8:30 - 10:00 a.m.	First Morning Session	
10:00 - 10:30 a.m.	Coffee Break	
10:30 - 12:00	Second Morning Session	
1:30 - 3:00 p.m.	First Afternoon Session	
3:00 - 3:30 p.m.	Coffee Break	
3:30 - 5:00 p.m.	Second Afternoon Session	

Sunday, November 10

First Morning Session - 8:30-10:00 a.m.

Opening remarks:

1. G.L. Thomas, Director Prince William Sound Science Center
2. Goals of the Conference - Ole Mathisen, Univ. of Alaska-Juneau
3. Prince William Sound Aquaculture Corporation - John McMullen, President
4. State Genetic Policy - Jim Seeb, Alaska Dept. of Fish & Game

Session 1 -- Ocean carrying capacity
10:30-12:00

1. *A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.* R. Ted Cooney
2. *Density dependent changes in chum salmon, Oncorhynchus Keta, returning to Iwate Prefecture, Japan.* Hitoshi Ida
3. *Factors affecting marine growth of Bristol Bay sockeye salmon.* Don Rogers

4. *Interaction in natural carrying capacity limitations for natural and enhanced stocks of salmon.* Percy Washington

Session 2 -- Management of mixed stocks
1:30-3:00 p.m.

1. *Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska.* Doug Eggers

2. *Management of mixed enhanced and wild salmonids in British Columbia.* (B.E. Riddell unable to attend - replacement???)

3. *Gene frequencies and the management of Pacific Salmon: Identification of wild and hatchery fish in mixed fisheries.* Jim Seeb

Session 3 -- Summary and general discussion
3:30-4:30 p.m.

Evening Seafood dinner at the Reluctant Fisherman
Social hour, 6:30 p.m.; Dinner, 7 p.m.

Monday, November 11

Session 4
8:30-10 am -- Basic Genetic Structure

1. *Conservation of genetic diversity in salmonid fishes: why, what and how.* P.W. Allendorf

2. *The productive value of stream distances for estimating genetic relationship in salmonid species.* Fred Utter

3. *Population structure of chum salmon.* Lina Seeb

4. *The importance of fine genetic structures in natural populations.* Tony Gharrett

Session 4 continued
10:30-12:00

5. *Quantitative genetic variation of life history traits in pink salmon.* William Smoker

6. *Genetic stock identification of Yukon River chum and chinook salmon.* Richard Wilmot

7. *Genetic stock identification of Bristol Bay area salmon.* Rebecca Everett.

Session 3 -- Straying
1:30 - 2:00 pm

1. *Homing, straying and the interaction between wild and enhanced stocks of salmon.* T.P. Quinn

2. *(TBA)* Sven Ebbesson (unable to attend -- paper to be distributed?)

Session 6 -- Long Term Case Histories
2:00-3:00 pm

1. *Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.* Tor Heggberget

2. *The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers.* Torleif Eriksson

Session 6 continued
3:30-5 pm

3. *The status of the Snake River chinook.* Ernest Brannon

4. *The Soviet experience in the field of salmon interactions.* Mikhail Glubokovsky

5. General discussion

Tuesday, November 12

Field trip to Wally Noerenberg Hatchery at Esther Island (western Prince William Sound) -- *Weather dependent, this may be delayed until Wednesday.*

Wednesday, November 13

Session 7 -- Interactions in Prince William Sound
8:30-10 am

1. *Historical production of wild and enhanced stocks of pink salmon in Prince William Sound.* Sam Sharr

Session 7 continued
10:30-12 noon -- Interactions in Prince William Sound

Session 8 -- Interactions in Southeast Alaska
1:30-3 pm

1. ***Chinook Enhancement in Southeast Alaska.*** Bill Heard

2. ***An Overview of the Pink, Chum and Coho Enhancement programs in Southeast Alaska.*** Don Amend

Session 8 continued
3:30-5 pm -- Interactions - General discussion

Thursday, November 14

Session 9 -- Interactions regarding other species, especially sockeye
8:30-10 am

Session 9 continued
10:30-12 Noon

Session 10 -- The Working Party: Writing sessions divided into sub-groups
1:30-5:00 pm

Friday, November 15

Session 11 -- Approval of document
8:30-12 Noon

Afternoon Departures

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WORKSHOP ON THE

BIOLOGICAL INTERACTIONS OF NATURAL AND ENHANCED

STOCKS OF SALMON IN ALASKA

History and Background

Hatchery operations of salmon and trout have been in progress for more than a century in Europe, North American and North Asia. For a long time little impact was felt on the natural stocks because the operations were small in scale and generally unsuccessful due to lacking biological understanding of the reproductive process and survival mechanisms in salmonid species. This has changed in Alaska, especially during the last couple of decades. Some enhancement project involving artificial propagations have produced startling results and the scope of operations are now large enough to profoundly affect natural stocks, the economic aspects of fishing and processing, and marketing.

However, no statements have been written to evaluate biological impacts which is one of the basic tasks of the proposed workshop. It is also a reflection on Alaska's present concern to preserve the natural heritage with which the State is endowed and that changes, some of an irreversible nature, must have the approval of all segments of the population.

Plans for a workshop on the biological interactions of natural and enhanced fish stocks in Alaska was initiated a year ago. It follows international meetings on this topic in Norway (1990, Institute of Nature Conservation), in Canada (1991, Department of Fisheries and Oceans), in Moscow, Idaho and Pullman Washington (1991, NATO), and in Hakodate (1991, University of Hokkaido). The impact of enhanced salmon on natural stocks was identified as one of five most important natural resources issues to the Greater Prince William Sound Area in a 1990 conference sponsored by the Science Center.

During the 1991 Alaska legislative session, the high abundance of salmon and low ex-vessel prices created caused concern about salmon enhancement projects throughout the State, of which the impacts of enhanced salmon on natural stocks is an important consideration. Four hatchery research project study groups were established by the Alaska State Senator Eliason, to research various questions regarding interactions between the fisheries for natural and enhanced stocks of salmon. The mission

of these groups is to prepare background material for a full scale debate by the Alaska State Legislature next spring. This workshop is independent of these legislative study groups, but complementary because it focuses in depth on the biological questions related to salmon enhancement.

Definitions and Constraints

1. Salmon enhancement is used synonymously with Ocean Ranching.

2. Pen farming of salmonid species will not be included.

3. Lake fertilization or other indirect enhancement measures such as habitat manipulation also fall outside the mandate.

Purpose

Non-profit hatchery operations and ocean ranching was legalized by the Alaska State Legislature in 1972. This occurred at a time when natural production was at a low point which also coincided with a low point of ocean temperatures. The purpose was to supplement the natural production and especially to smooth out some of the existing interannual variability. But the mandate by the Legislature to the regulatory agencies was to manage for the natural stocks and this became a Public Policy.

In the beginning this was not a problem as long as the ocean ranching took place on a limited scale. In recent years with favorable survival conditions both natural and enhanced stocks have reached unprecedented magnitudes. In some areas of successful hatchery operations natural populations have declined. Thus, the major question for the workshop is to examine:

"The Biological Basis for Maintaining Strong Coexisting Stocks of Natural and Enhanced Salmon Populations in Alaska"

In this short statement is embodied all the biological problems of the Alaskan salmon populations involving behavior and straying, cross breeding and survival rates, ocean carrying capacity and harvest rates.

Objectives

1. To examine and evaluate the relevant genetic and behavioral characteristics of natural and enhanced stocks of salmonid fishes as they relate to hatchery issues in Alaska.

2. To consider life, mortality, or survival tables for fresh water, estuarine, coastal jet, and oceanic environments, linked in space and time, for natural and enhanced stocks of salmon in Alaska.

3. To examine relevant groupings of time series case histories of interactions of natural and enhanced stocks of salmon outside Alaska.

4. To explore limits to the carrying capacity of the ocean environment in the Gulf of Alaska.

Organization

The workshop will convene a small group of experts by invitations in Cordova, Alaska under the auspices of the Prince William Sound Science Center and the School of Fisheries and Ocean Sciences at the University of Alaska, Fairbanks. The participants fall into three categories: International experts, National experts outside Alaska, and experts from inside Alaska. Many of the participants will be asked to prepare papers on topics related to the workshops objectives.

These invited papers will be circulated for peer review, edited by the workshop chairpersons, and submitted for a special issue (workshop proceedings) publication.

In recognition of the complexity of this issue and the limited amount of synoptic information to evaluate it, unanimous conclusions and recommendations are not anticipated so the underlying risk functions of different courses of action must be considered.

The workshop will be organized around 5 separate Sessions:

1. The basic genetic structures of salmon stocks.

2. Time series of hatchery data and experiments from non-Alaskan sources.

3. Interactions Issues in Alaska

This session will be organized by three species groupings (pink-chum, sockeye, chinook-coho) or by two geographic areas, Prince William Sound and Southeast Alaska. Kodiak and Cook Inlet information will be used if appropriate. This latter alternative might be advantageous due to the interaction between grouping of species.

4. Carrying Capacity of the Ocean

5. Summary of Results and Conclusions with some Recommendations for Future High Priority Directed Research.

A Discussant will be appointed for each Session with the assignment of drafting a Report to be presented in the final session.

Following the Workshop these reports will be polished off and assembled whereafter a small Review and Editorial Group will meet in Juneau or elsewhere for completion of the final Group Report. The individual session reports or final report will be treated as the invited papers: circulated for peer review, edited, and submitted with the invited papers as a special issue (workshop proceedings) publication. A scientific journal will be sought as the publisher, pending quality of the papers.

Methods

The workshop will be convened on November 10 and run continuously through the 15th. Expenses will be provided to all international guests and to those North American participants that require it.

Products

December 1991: A final report on the Workshop sessions.

June 1992: Submission of the Workshop Proceedings as an issue of a scientific journal.

Sponsorship

This workshop is sponsored by the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences (SFOS) University of Alaska, Fairbanks.

Co-chairpersons are Dr. A. Ole Mathisen, SFOS, and Dr. G.L. Thomas, PWSSC. The list of contributors include: Alaska Department of Fish and Game, Pacific Seafood Processors Association, Pew Charitable Trust, Prince William Sound Aquaculture Association, Sealaska Corporation, and University of Alaska Fairbanks.

PRINCE WILLIAM SOUND SCIENCE CENTER
CORDOVA ALASKA

P.O. Box 705
Cordova, AK 99574
(907) 424-5800 FAX: (907) 424-5820

Workshop on the
"Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska"

DATES: Sunday, Nov. 10 - Friday, Nov. 15, 1991

AT: Masonic Hall and the Prince William Sound Science Center
Cordova, Alaska

ORGANIZERS: Prince William Sound Science Center and the School of Fisheries and Ocean Sciences, University of Alaska

OBJECTIVES:

1. To examine and evaluate the relevant genetic and behavioral characteristics of natural and enhanced stocks of salmonid fishes as they relate to hatchery issues in Alaska.

2. To consider life, mortality, or survival tables for fresh water, estuarine, coastal jet, and oceanic environments, linked in space and time, for natural and enhanced stocks of salmon in Alaska.

3. To examine relevant groups of time series case histories of interactions of natural and enhanced stocks of salmon outside Alaska.

4. To explore limits to the carrying capacity of the ocean environment in the Gulf of Alaska.

The major question for this workshop is to examine:

"The biological basis for maintaining strong coexisting stocks of natural and enhanced salmon populations in Alaska."

AGENDA

The workshop will convene a small group of experts from the international community, from elsewhere in North America and from inside Alaska. During the first two days of the workshop, *which are open to the general public,* papers will be presented on topics related to the workshop's objectives. A tentative list of the speakers and their topics is attached.

The latter days of the workshop will involve the experts in small group work sessions and a writing session. A summary of the

results and any conclusions reached will be approved at the final workshop session Friday morning, Nov. 15.

A final report on the workshop will be completed in December 1991. The papers presented will be circulated for peer review, edited by the workshop chairpersons and submitted for publication in June 1992.

WORKSHOP CHAIRPERSONS: Ole Mathisen, *School of Fisheries, University of Alaska, Juneau, Alaska*
G.L. (Gary) Thomas, *Director, Prince William Sound Science Center, Cordova, Alaska*

The list of contributors includes:
The Pew Charitable Trusts
Alaska Department of Fish & Game
Pacific Seafood Processors Association
Prince William Sound Aquaculture Corporation
Sealaska Corporation
School of Fisheries and Ocean Science, University of Alaska
Prince William Sound Science Center

For further information: Nancy Bird, (907) 424-5800 or
FAX 424-5820

Gary T... in Seattle
206-543-6475

Tentative list of Workshop Participants and their Topics

Conservation of genetic diversity in salmonid fishes: why, what and how.
F.W Allendorf, Division of Biological Sciences, Missoula, Montana

An Overview of the Pink, Chum and Coho Enhancement programs in Southeast Alaska.
Don Amend, Southern Southeast Regional Aquaculture Association, Ketchikan, Alaska

The status of the Snake River chinook.
Ernest Brannon, University of Idaho, Moscow, Idaho

A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.
Ted Cooney, School of Fisheries & Ocean Sciences, University of Alaska, Fairbanks, Alaska

~~Sven Ebbesson, Institute of Marine Science, University of Alaska, Seward, Alaska~~ - unable to attend

Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska.
Doug Eggers, Chief Fisheries Scientist, Alaska Dept. of Fish & Game, Juneau, Alaska

Torleif Eriksson, Swedish Univ. of Agricultural Sciences, Department of Aquaculture, Umea, Sweden

The importance of fine genetic structures in natural populations.
Tony Gharrett, School of Fisheries, University of Alaska, Juneau, Alaska

The Soviet experience in the field of salmon interactions.
Mikhail Glubokovsky, Institute of Marine Biology, Far East Branch, Vladivostok, USSR

Chinook Enhancement in Southeast Alaska.
Bill Heard, National Marine Fisheries Service, Juneau, Alaska

Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.
Tor Heggberget, NINA, Norsk Institutt for Naturforskning, Trondheim, Norway

Density dependent changes in chum salmon, Oncorhynchus Keta, returning to Iwate Prefecture, Japan.
Hitoshi Ida, Kitasato University School of Fisheries Sciences, Sanriku-cho, Kesen-gun, Japan

Ole Mathisen, Director, Fisheries School, University of Alaska, Juneau, Alaska

John McMullen, President, Prince William Sound Aquaculture Corporation, Cordova, Alaska

Homing, straying and the interaction between wild and enhanced stocks of salmon.
T.P. Quinn, Fisheries Research Institute, University of Washington, Seattle, Washington

~~*Management of mixed enhanced and wild salmonids in British Columbia.*~~
~~B. R. Riddell, Dept. of Fisheries and Ocean, Biological Sciences Branch, Nanaimo, British Columbia, Canada~~ unable to attend
replacement being sought

Factors affecting marine growth of Bristol Bay sockeye salmon.
Don Rogers, Fisheries Research Institute, University of Washington, Seattle, Washington

Gene frequencies and the management of Pacific Salmon: Identification of wild and hatchery fish in mixed fisheries.
Jim Seeb, Alaska Dept. of Fish & Game, Anchorage, Alaska

Population Structure of Chum Salmon
Lisa Seeb, Alaska Dept. of Fish & Game, Anchorage, Alaska

Sam Sharr, Research Biologist, Alaska Dept. of Fish & Game, Cordova, Alaska

Bill Smoker, School of Fisheries, University of Alaska, Juneau, Alaska

Gary Thomas, Director, Prince William Sound Science Center, Cordova, Alaska

The productive value of stream distances for estimating genetic relationship in salmonid species.
Fred M. Utter, National Oceanic and Atmospheric Administration (NOAA), Seattle, Washington

Percy Washington, GAIA NW Inc., Seattle, Washington

Additions

Rebecca Everett, USFWS

Richard Wilmot USFWS

TENTATIVE AGENDA
Workshop on the
"Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska"

Saturday, November 9

Participants arrive during the day.

6:00-7:30 pm Welcoming reception, at the Powder House (transportation provided).

All the plenary meetings are held in the Masonic Hall (located at the north end of First Street). The daily schedule is as follows:

7:45 - 8:30	a.m.	Continental Breakfast (at the Masonic Hall)
8:30 - 10:00	a.m.	First Morning Session
10:00 - 10:30	a.m.	Coffee Break
10:30 - 12:00		Second Morning Session
1:30 - 3:00	p.m.	First Afternoon Session
3:00 - 3:30	p.m.	Coffee Break
3:30 - 5:00	p.m.	Second Afternoon Session

Sunday, November 10

First Morning Session - 8:30-10:00 a.m.

Opening remarks:

1. G.L. Thomas, Director Prince William Sound Science Center
2. Goals of the Conference - Ole Mathisen, Univ. of Alaska-Juneau
3. Prince William Sound Aquaculture Corporation - John McMullen, President
4. State Genetic Policy - Jim Seeb, Alaska Dept. of Fish & Game

Session 1 -- Ocean carrying capacity
10:30-12:00

1. *A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.* R. Ted Cooney
2. *Density dependent changes in chum salmon, Oncorhynchus Keta, returning to Iwate Prefecture, Japan.* Hitoshi Ida
3. *Factors affecting marine growth of Bristol Bay sockeye salmon.* Don Rogers

4. *Interaction in natural carrying capacity limitations for natural and enhanced stocks of salmon.* Percy Washington

Session 2 -- Management of mixed stocks
1:30-3:00 p.m.

1. *Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska.* Doug Eggers

2. *Management of mixed enhanced and wild salmonids in British Columbia.* (B.E. Riddell unable to attend - replacement???)

3. *Gene frequencies and the management of Pacific Salmon: Identification of wild and hatchery fish in mixed fisheries.* Jim Seeb

Session 3 -- Summary and general discussion
3:30-4:30 p.m.

Evening Seafood dinner at the Reluctant Fisherman
Social hour, 6:30 p.m.; Dinner, 7 p.m.

<u>Monday, November 11</u>

Session 4
8:30-10 am -- **Basic Genetic Structure**

1. *Conservation of genetic diversity in salmonid fishes: why, what and how.* F.W. Allendorf

2. *The productive value of stream distances for estimating genetic relationship in salmonid species.* Fred Utter

3. *Population structure of chum salmon.* Lisa Seeb

4. *The importance of fine genetic structures in natural populations.* Tony Gharrett

Session 4 continued
10:30-12:00

5. *Quantitative genetic variation of life history traits in pink salmon.* William Smoker

6. *Genetic stock identification of Yukon River chum and chinook salmon.* Richard Wilmot

7. *Genetic stock identification of Bristol Bay area salmon.* Rebecca Everett.

Session 5 -- Straying
1:30 - 2:00 pm

1. *Homing, straying and the interaction between wild and enhanced stocks of salmon.* T.P. Quinn

2. *(TBA)* Sven Ebbesson (unable to attend -- paper to be distributed?)

Session 6 -- Long Term Case Histories
2:00-3:00 pm

1. *Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.* Tor Heggberget

2. *The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers.* Torleif Eriksson

Session 6 continued
3:30-5 pm

3. *The status of the Snake River chinook.* Ernest Brannon

4. *The Soviet experience in the field of salmon interactions.* Mikhail Glubokovsky

5. General discussion

<u>Tuesday, November 12</u>

Field trip to Wally Noerenberg Hatchery at Esther Island (western Prince William Sound) -- *Weather dependent, this may be delayed until Wednesday.*

<u>Wednesday, November 13</u>

Session 7 -- Interactions in Prince William Sound
8:30-10 am

1. *Historical production of wild and enhanced stocks of pink salmon in Prince William Sound.* Sam Sharr

Session 7 continued
10:30-12 noon -- Interactions in Prince William Sound

Session 8 -- Interactions in Southeast Alaska
1:30-3 pm

1. *Chinook Enhancement in Southeast Alaska.* Bill Heard
2. *An Overview of the Pink, Chum and Coho Enhancement programs in Southeast Alaska.* Don Amend

Session 8 continued
3:30-5 pm -- Interactions - General discussion

Thursday, November 14

Session 9 -- Interactions regarding other species, especially sockeye
8:30-10 am

Session 9 continued
10:30-12 Noon

Session 10 -- The Working Party: Writing sessions divided into sub-groups
1:30-5:00 pm

Friday, November 15

Session 11 -- Approval of document
8:30-12 Noon

Afternoon Departures

final recommendations
wrap-up

List of speakers invited to Workshop on the Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska
November 9 - 15, 1991 -- Cordova, Alaska

Sponsored by the Prince William Sound Science Center and the University of Alaska - School of Fisheries

F.W. Allendorf
Division of Biological Sciences
University of Montana
Missoula, Montana 59812-1002
Phone:(406) 243-5503
FAX:(406) 243-4184
Topic: Conservation of genetic diversity in salmonid fishes: why, what and how.

Don Amend
Director
Southern SE Regional Aquaculture Assoc.
1621 Tongass
Ketchikan, Alaska
Phone: (907) 225-9605
FAX: (907) 225-1348
Topic: An overview of the pink, chum, coho enhancement programs in Southeast Alaska.

Don Bailey
Salmon Enhancement Program
Department of Fisheries & Oceans

Vancouver, Canada
Phone: (604) 666-2949
FAX: (604) 666-6894
Topic: Management of mixed enhanced and wild salmonids in British Columbia.

Ernest Brannon
University of Idaho
College of Forestry
Moscow, Idaho 83843
Phone: (208) 885-5830 or 885-7323
FAX: (208) 885-5968
Topic: The perpetual oversight of hatchery programs.

Ted Cooney
School of Fisheries & Ocean Sciences
University of Alaska
231 Irving II
Fairbanks, Alaska 99775-1080
Phone: (907) 474-7407
FAX: (907) 474-7204
Topic: A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.

Doug Eggers
Chief Fisheries Scientist
Alaska Dept. of Fish & Game
P.O. Box 25526
Juneau, Alaska 99802-5526
Phone: (907) 465-4210
FAX: 465-2604
Topic: Trends in Abundance of Hatchery and Wild Stocks of Pink Salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska

Torleif Eriksson
Swedish Univ. of Agricultural Sciences
Department of Aquaculture
Box 1457
S-90124 Umea, Sweden
Phone: 46 90 19 00 10
FAX: 46 90 19 09 87
Topic: The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers.

Rebecca Everett
Fishery Biologist
U.S. Fish & Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503
Phone: (907) 786-3318
FAX (907) 786-3350
Topic: Genetic relationships among Pacific salmon the of the Bristol Bay area of Alaska.

Tony Gharrett
School of Fisheries
University of Alaska
11120 Glacier Highway
Juneau, Alaska 99803
Phone: (907) 789-4442
FAX:(907) 789-4447
Topic: The importance of fine genetic structures in natural populations.

Mikhail Glubokovsky
Institute of Marine Biology
Far East Branch
Academy of Sciences of the USSR
Vladivostok 690032, USSR
Phone: 296-205-202
FAX: (423) 2-242-589
Topic: The Soviet experience in the field of salmon interactions.

Bill Heard
National Marine Fisheries Service
P.O. Box 210029
Juneau, Alaska 99801
Phone: (907) 789-6003
FAX: 789 6094
Topic: Southeast Alaska Chinook; Fisheries, management, enhancement, wild stocks and treaties.

Tor Heggberget
NINA
Norsk Institutt for Naturforskning
Tungasletta 2 N.7004
Trondheim, Norway
Phone: (47 7) 58 05 00
FAX: (47 7) 91 54 33
Topic: Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.

Hitoshi Ida
Kitasato University
School of Fisheries Sciences
Sanriku-cho, Kesen-gun
Iwate, 022-01, Japan
Phone: (81) 192-44-2121
FAX: (81) 192-44-2125
Topic: Density dependent changes in chum salmon, Oncorhynchus Keta, returning to Iwate Prefecture, Japan.

Ole Mathisen
Director, Fisheries School
Univ. of Alaska
11120 Glacier Highway
Juneau, Alaska 99803
Phone: (907) 789-4442 or 789-9269
FAX: (907) 789-4447
Topic: Goals of the conference

John McMullen
President
Prince William Sound Aquaculture Corporation
P.O. Box 1110
Cordova, Alaska 99574
Phone: (907) 424-7511
FAX: (907) 424-7514
Topic: Overview of the PWSAC program.

T.P. Quinn
Fisheries Research Institute
University of Washington
WH-10
Seattle, Washington 98195
Phone: (206) 543-9042
FAX: (206) 685-7471
Topic: Homing, straying and the interaction between wild and enhanced stocks of salmon.

Don Rogers
Fisheries Research Institute
University of Washington
WH-10
Seattle, Washington 98195
Phone: (206) 543-7628
FAX: (206) 685-7471
Topic: Factors affecting marine growth of Bristol Bay sockeye.

Jim Seeb
Alaska Dept. of Fish & Game
333 Raspberry Road
Anchorage, Alaska 99518-1599
Phone: (907) 267-2385
FAX: 349-5532
Topic: Gene frequencies and the management of Pacific Salmon: Identification of wild and hatchery fish in mixed fisheries.

Lisa Seeb
Alaska Dept. of Fish & Game
333 Raspberry Road
Anchorage, Alaska 99518-1599
Phone: (907) 267-2249
FAX: 344-9238
Topic: Population genetic structure of chum salmon: identification of wild and hatchery fish in mixed fisheries.

Sam Sharr
Research Biologist
Alaska Dept. of Fish & Game
P.O. Box 669
Cordova,, Alaska 99574
Phone: (907) 424-3213
FAX: (907) 4424-3235
Topic: Historical production of wild and enhanced stocks of pink salmon in Prince William Sound.

Bill Smoker
School of Fisheries
University of Alaska
11120 Glacier Highway
Juneau,, Alaska 99803
Phone: (907) 789-4442
FAX: (907) 789-4447
Topic: Quantitative genetic variation of life history traits in pink salmon.

Gary Thomas
Director
Prince William Sound Science Center
P.O. Box 6009
Lynnwood, Washington 98036
Phone: (206) 543-6475
FAX: (206) 685-7471
Topic: Overview of the PWS Science Center program.

Fred M. Utter
NOAA
2725 Montlake Blvd. E.
Seattle, Washington 98112
Phone: (206) 553-7781 or messages 553-4445
FAX: (206) 553-4313
Topic: The predictive value of stream distances for estimating genetic relationships in salmonid species.

Percy Washington
Gaia NW Inc.
10522 Lake City Way NE Suite 201
Seattle, Washington 98125
Phone: (206) 367-2864
FAX: (206) 367-2865
Topic: Interaction in natural carrying capacity limitations for natural and enhanced stocks of salmon.

Richard Wilmot
Research Fishery Biologist
U.S. Fish & Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503
Phone: (907) 786-3312
FAX: (907) 786-3636
Topic: Genetic stock identification of Yukon River chum and chinook salmon.

Juneau Center for Fisheries and Ocean Sciences
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
11120 Glacier Highway
Juneau, Alaska 99801
(907) 789-4441 Office
(907) 789-4447 FAX

2 December 1991

MEMORANDUM

To: Mollly Mc[illegible]
Fr: Ole A. Mathisen OAM
Re: Some personal reflections on the Cordova Workshop

1. Genetic Diversity

The message came through very loud and clear that genetic diversity must be preserved. In Norway this has largely been lost due to extensive transfer of brood stocks and escapees from pens. Sweden offers a contrast where salmon habitat has been lost due to hydroelectric dam building 30 - 40 years ago. Nevertheless the stocks and their genetic diversity have been maintained by hatchery operations without transfer between rivers or remote site planting.

2. Straying

We do not know the extent of straying or the mechanism causing imprinting. But when ocean ranching assumes the proportion seen in Prince William Sound the stage is set for straying of wild stocks in the harvest areas of enhanced stocks and also for hatchery fish to stray in the natural streams. Neither do we know how successful cross breeding will be. This clearly raises the question if a cap should be placed on enhancement activities and if so how large should this cap be?

3. Planting at Remote Locations

We know that straying increases with distance of release from donor stream or hatchery. The extensive releases at remote sites which are practiced today and much more planned for the future could potentially in time destroy genetic diversity. Furthermore if this happens, the process is irreversible and the loss is permanent. It is my opinion that we are gambling by allowing these practices without any real knowledge of the imprinting process and straying. Here lies one of the prime research areas for which the cost should largely be underwritten by the hatcheries and to some extent by the ADF&G.

4. Ocean Carrying Capacity

It was probably the general feeling of the group that we might approach an upper limit since all salmon were extremely small on both sides of the Pacific Ocean in 1991.

Opinions differed whether this happened on the outmigration or in the nearshore environment on the return migration. There probably are enough monitoring stations to follow the changing productivity of the North Pacific Ocean.

These are some points which need much more clarification and I have listed them for your own information.

Juneau Center for Fisheries and Ocean Sciences
University of Alaska Fairbanks
11120 Glacier Highway
Juneau, Alaska 99801 (907) 789-4441

11 May 1991

Carl L. Rosier, Commissioner of Fisheries
Alaska Department of Fish and Game
1255 West 8th Street
P.O.Box 3-2000
Juneau, Alaska 99802-2000

Dear Carl:

Due to a previous workshop commitment in Seattle it is very difficult for me to attend the meeting called by Senator Dick Eliason on Wednesday, May 15, at 1:30 in the Butrovich Room regarding hatcheries and hatchery programs in Alaska. The purpose of the meeting is to identify major topics and to formulate specific questions regarding hatcheries which should be researched and adressed by the Legislature.

As I see it there are specific genetic questions involved in any hatchery program. The State already has a standing committee for answering such questions and to develop guidelines for future work. Dr. Tony Gharrett from the Juneau Center for Fisheries and Ocean Sciences is a member of this group.

Then there are a number of social and economic questions with some far reaching consequences and Lee Gorsuch has expressed an interest in such problems.

My effort to convene a workshop deals with the biological aspects of the hatchery program and the interaction between wild and enhanced stocks. This question has been raised in Norway, it will be discussed in Nanaimo in June this year and later at a NATO sponsored conference at Washington State University in Pulman.

An observed decline of wild stocks of pinks in Prince William Sound with its massive ocean ranching program has prompted the question of any link and raised the following questions:

1. What is the extent of straying of enhanced stocks of pinks or any other enhanced salmon?

2. What is the reproductive success of stray cultured and wild salmon?

3. To what extent will wild fish school together with enhanced stocks and eventually be caught in a restricted harvest area.

4. What is the carrying capacity of the feeding areas in the Gulf of Alaska, not only for pink salmon but also for sockeye salmon from other districts like Bristol Bay using the same feeding grounds?

5. What is the value of an undisturbed gene pool which has developed over the last 10 -12 000 years since the ice cap receded?

Although the proposed workshop should only deal with Alaskan problems, it would be advantageous to solicit the assistance of a few experts from abroad. In Norway, Japan and the USSR enhancement programs have been practiced for a long time.

I feel confident that the workshop could conclude its work before the next session of the Legislature; but I also expect that there will remain some unanswered questions, which eventually may call for additional research. I have tentatively estimated the cost of a workshop convened at least for one week, to be $ 50 000, half of which may come from new Science Center in Cordova.

One purpose of this letter is to convy to you Dean Alexanders interest in utilizing the talent of the School of Fisheries and Ocean Sciences and especially of the Juneau based group in assisting the State in solving some of the problems raised above.

Sincerely yours,

Ole A. Mathisen

cc: Representative Ulmer
Dr. Burkett
Dean Alexander

Alaska State Legislature

SENATOR RICHARD I. ELIASON

President of the Senate

P.O. Box V
Juneau, Alaska 99811
(907) 465-3755

MEMORANDUM

TO: Pam Stoops, Director
Administrative Services Division
Legislative Affairs Agency

FROM: Sen. Dick Eliason
Senate President

DATE: October 7, 1991

RE: Expenditure of funds for Workshop: "Biological Interactions of Natural and Enhanced Fish Stocks in Alaska" through School of Fisheries and Ocean Sciences

This memo authorizes the expenditure of Senate leadership funds in the amount of $4,975 through the School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, for the workshop "Biological Interactions of Natural and Enhanced Fish Stocks in Alaska."

A copy of the projected budget for the workshop, and a summary of workshop objectives is attached. The funds provided by the Legislature are to be used to assist in paying travel and and expenses for workshop participants. The workshop is scheduled for Nov. 10 - 15, and is jointly sponsored by the School of Fisheries and Ocean Sciences (U of A, Fairbanks) and the Prince William Sound Science Center. The workshop is complementary to the work being conducted by the Legislature's hatchery research project now underway in that it focuses in depth on the biological questions related to salmon enhancement, including the genetic impact of interaction between wild and hatchery stocks. Products of the

workshop will include a final report on the workshop's sessions, which will be useful to the Legislative Hatchery Research Project, to the Senate Special Committee on Domestic and International Fisheries, and to individual members of the Legislature as this issue of the state's fisheries enhancement program is taken up during the next session.

It is my understanding that this funding will not be subject to the University's usual administrative overhead. If you have any questions, please contact my office.

WORKSHOP

BIOLOGICAL INTERACTIONS OF NATURAL AND ENHANCED FISH STOCKS IN ALASKA

PROJECTED BUDGET
(October 1, 1991)

Salaries and Benefits	
Science Center	
organization, secretarial, etc.	N.C.
University of Alaska	
organization, secretarial, etc.	N.C.
Services	
Publication $65/page @ 120 pages	$ 7,800
Room rentals	1,000
Equipment rentals	
4 IBM computers (Science Center, Mathisen, others)	N.C.
Speaker system	200
Flight to hatcheries	1,500
Telephone	
Science Center	500
University of Alaska	500
Supplies	
Miscellaneous conference materials	700
Zippered conference pouches	300
Travel	
Overseas airfares - 21 day advance purchase	8,000
Domestic airfares - 14 day advance purchase	9,000
Per diem	
rooms - 22 people @ $60 for 5 nights	6,600
meals - 22 people @ $40 for 6 days	5,280
overseas travel 3 @ $50 for 2 days	300
2 persons (Doug Eggers & Lisa Seeb)	N.C.
Miscellaneous/contingency	500
Contingency	1,295
TOTAL	$ 43,475

WORKSHOP

BIOLOGICAL INTERACTIONS OF NATURAL AND ENHANCED FISH STOCKS IN ALASKA

CONTRIBUTORS

Prince William Sound Science Center	$ 22,500
Sealaska Corporation	1,000
University of Alaska	5,000
Alaska Dept. of Fish & Game	5,000
Pacific Seafood Processors Association	5,000
Other contributions	4,975
TOTAL	$ 43,475

Juneau Center for Fisheries and Ocean Sciences

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WORKSHOP ON THE

BIOLOGICAL INTERACTIONS OF NATURAL AND ENHANCED

STOCKS OF SALMON IN ALASKA

History and Background

Hatchery operations of salmon and trout have been in progress for more than a century in Europe, North American and North Asia. For a long time little impact was felt on the natural stocks because the operations were small in scale and generally unsuccessful due to lacking biological understanding of the reproductive process and survival mechanisms in salmonid species. This has changed in Alaska, especially during the last couple of decades. Some enhancement project involving artificial propagations have produced startling results and the scope of operations are now large enough to profoundly affect natural stocks, the economic aspects of fishing and processing, and marketing.

However, no statements have been written to evaluate biological impacts which is one of the basic tasks of the proposed workshop. It is also a reflection on Alaska's present concern to preserve the natural heritage with which the State is endowed and that changes, some of an irreversible nature, must have the approval of all segments of the population.

Plans for a workshop on the biological interactions of natural and enhanced fish stocks in Alaska was initiated a year ago. It follows international meetings on this topic in Norway (1990, Institute of Nature Conservation), in Canada (1991, Department of Fisheries and Oceans), in Moscow, Idaho and Pullman Washington (1991, NATO), and in Hakodate (1991, University of Hokkaido). The impact of enhanced salmon on natural stocks was identified as one of five most important natural resources issues to the Greater Prince William Sound Area in a 1990 conference sponsored by the Science Center.

During the 1991 Alaska legislative session, the high abundance of salmon and low ex-vessel prices created caused concern about salmon enhancement projects throughout the State, of which the impacts of enhanced salmon on natural stocks is an important consideration. Four hatchery research project study groups were established by the Alaska State Senator Eliason, to research various questions regarding interactions between the fisheries for natural and enhanced stocks of salmon. The mission

of these groups is to prepare background material for a full scale debate by the Alaska State Legislature next spring. This workshop is independent of these legislative study groups, but complementary because it focuses in depth on the biological questions related to salmon enhancement.

Definitions and Constraints

1. Salmon enhancement is used synonymously with Ocean Ranching.

2. Pen farming of salmonid species will not be included.

3. Lake fertilization or other indirect enhancement measures such as habitat manipulation also fall outside the mandate.

Purpose

Non-profit hatchery operations and ocean ranching was legalized by the Alaska State Legislature in 1972. This occurred at a time when natural production was at a low point which also coincided with a low point of ocean temperatures. The purpose was to supplement the natural production and especially to smooth out some of the existing interannual variability. But the mandate by the Legislature to the regulatory agencies was to manage for the natural stocks and this became a Public Policy.

In the beginning this was not a problem as long as the ocean ranching took place on a limited scale. In recent years with favorable survival conditions both natural and enhanced stocks have reached unprecedented magnitudes. In some areas of successful hatchery operations natural populations have declined. Thus, the major question for the workshop is to examine:

"The Biological Basis for Maintaining Strong Coexisting Stocks of Natural and Enhanced Salmon Populations in Alaska"

In this short statement is embodied all the biological problems of the Alaskan salmon populations involving behavior and straying, cross breeding and survival rates, ocean carrying capacity and harvest rates.

Objectives

1. To examine and evaluate the relevant genetic and behavioral characteristics of natural and enhanced stocks of salmonid fishes as they relate to hatchery issues in Alaska.

2. To consider life, mortality, or survival tables for fresh water, estuarine, coastal jet, and oceanic environments, linked in space and time, for natural and enhanced stocks of salmon in Alaska.

3. To examine relevant groupings of time series case histories of interactions of natural and enhanced stocks of salmon outside Alaska.

4. To explore limits to the carrying capacity of the ocean environment in the Gulf of Alaska.

Organization

The workshop will convene a small group of experts by invitations in Cordova, Alaska under the auspices of the Prince William Sound Science Center and the School of Fisheries and Ocean Sciences at the University of Alaska, Fairbanks. The participants fall into three categories: International experts, National experts outside Alaska, and experts from inside Alaska. Many of the participants will be asked to prepare papers on topics related to the workshops objectives.

These invited papers will be circulated for peer review, edited by the workshop chairpersons, and submitted for a special issue (workshop proceedings) publication.

In recognition of the complexity of this issue and the limited amount of synoptic information to evaluate it, unanimous conclusions and recommendations are not anticipated so the underlying risk functions of different courses of action must be considered.

The workshop will be organized around 5 separate Sessions:

1. The basic genetic structures of salmon stocks.

2. Time series of hatchery data and experiments from non-Alaskan sources.

3. Interactions Issues in Alaska

This session will be organized by three species groupings (pink-chum, sockeye, chinook-coho) or by two geographic areas, Prince William Sound and Southeast Alaska. Kodiak and Cook Inlet information will be used if appropriate. This latter alternative might be advantageous due to the interaction between grouping of species.

4. Carrying Capacity of the Ocean

5. Summary of Results and Conclusions with some Recommendations for Future High Priority Directed Research.

A Discussant will be appointed for each Session with the assignment of drafting a Report to be presented in the final session.

Following the Workshop these reports will be polished off and assembled whereafter a small Review and Editorial Group will meet in Juneau or elsewhere for completion of the final Group Report. The individual session reports or final report will be treated as the invited papers: circulated for peer review, edited, and submitted with the invited papers as a special issue (workshop proceedings) publication. A scientific journal will be sought as the publisher, pending quality of the papers.

Methods

The workshop will be convened on November 10 and run continuously through the 15th. Expenses will be provided to all international guests and to those North American participants that require it.

Products

December 1991: A final report on the Workshop sessions.

June 1992: Submission of the Workshop Proceedings as an issue of a scientific journal.

Sponsorship

This workshop is sponsored by the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences (SFOS) University of Alaska, Fairbanks.

Co-chairpersons are Dr. A. Ole Mathisen, SFOS, and Dr. G.L. Thomas, PWSSC. The list of contributors include: Alaska Department of Fish and Game, Pacific Seafood Processors Association, Pew Charitable Trust, Prince William Sound Aquaculture Association, Sealaska Corporation, and University of Alaska Fairbanks.

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4/65 - 4523

20 August 1991

The Honorable Senator R.I. Eliason
P.O.Box 143
Sitka
Alaska 99835

Dear Senator Eliason:

After a conference in Norway in the Spring of 1990 on the "Interaction of Natural and Enchanced Stocks of Salmon" I realized that the same question soon would be raised in Alaska and I started to plan a workshop on the biological aspects of the problem. Since that time there have been Conferences and Symposia on the same subject matter in B.C., Washington, Idaho, Japan and in the USSR.

You realized the same need by appointing the four Legislative Committees with a very broad mandate. I have been in touch with several of the committee members and see little overlap, rather the Workshop planned by the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks and the Prince William Sound Science Centere will interphase well and compliment the work by your committees. We are not planning any new research. Rather our main function will be not only to summarize recent biological findings but also to evaluate them in context of the stated goal of the workshop. An important part is to identify the unknown areas, and there are many, and to suggest and prioritize future research while we also look at the risk of some decisions involving unknown factors.

I am enclosing a short Prospectus and a Budget Statement. We have collected $ 40 000 from private sources and will hold the Workshop within the given framework. It had been my hope to have $ 50 000 at our disposal since there still are some important people missing. So the bottom line of this long letter is a question whether you are in a position to contribute something to this workshop. If you have additional question I shall be happy to meet with you in Sitka.

Sincerely yours,

Ole A. Mathisen

Ole A. Mathisen
Professor of Fisheries

Post-it™ brand fax transmittal memo 7671 | # of pages ▸ 6

To Laura	From Sen. Eliason
Co. Sen. Eliason's Office	Co.
Dept.	Phone #
Fax #	Fax #

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LEGIBLY BECAUSE OF THE POOR QUALITY OF THE
ORIGINAL

Science Lecture Series Program
Sponsored by the Prince William Sound Science Center and Prince William Sound Aquaculture Corporation

Friday, September 20, 1991 -- 7:30 p.m.

Old courtroom, U.S. Forest Service Building
2nd Street

Salmon Production in Prince William Sound:

Are wild salmon fry being disadvantaged by large scale releases of hatchery fry?

R. Ted Cooney
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Studies presently underway in Prince William Sound are testing the assertion that salmon production in the region is limited, in large part, by natural factors affecting the growth rates of fry during early ocean residence. Results to date implicate year-to-year variations in ocean temperature and fry food stocks as the major factors affecting run size. High levels of food and warm spring time temperatures favor elevated fry growth rates, reducing the time that juveniles spend at small, vulnerable sizes. Conversely, cold springs and poor food abundance generally translate into poorer overall future production. Cooperative Fisheries and Oceanographic Studies (CFOS) is jointly sponsored by the University of Alaska, the non-profit hatcheries and the Alaska Department of Fish and Game to describe the effects of coastal ocean temperature on salmon production in the Sound.

Dr. Cooney will discuss historical trends in salmon production in the Sound relative to oceanographic cycles in temperature and plankton in the Gulf of Alaska in addressing the question of whether or not the carrying capacity of the Sound is being approached by increasing hatchery releases. The planned operation of a new meteorological and oceanographic buoy and future plans for salmon studies in the region will also be covered in light of a predicted return to below average ocean temperatures in the Gulf.

The general public and fishing community are urged to attend this lecture and to participate in the question and answer session following Dr. Cooney's remarks. This talk is co-sponsored by the Prince William Sound Aquaculture Corporation and the Prince William Sound Science Center.

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A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska for Juvenile Pacific Salmon

R. Ted Cooney
Institute of Marine Science
University of Alaska Fairbanks

Abstract

The present feeding demand on zooplankton resources by wild and ocean ranched juvenile Pacific salmon in Prince William Sound is estimated between 1.0 and 4.0 percent of the total "herbivore" production, and 4.0 to 16.0 percent of the annual macrozooplankton production in the region. When annual fry losses to early ocean mortality are taken into account, the feeding demand associated with growth rates averaging 3 to 4 percent of the body weight per day fall to 0.4 to 1.6 percent of the total herbivore production and 1.5 to 5.0 percent of the macrozooplankton production. Uncertainties associated with the numerous assumptions used in this analysis are discussed in relation to what is understood about the biology and ecology of salmon in Prince William Sound and elsewhere.

Introduction

Successes with ocean ranching of Pacific salmon in Prince William Sound, Alaska are beginning to raise management and enhancement questions about the ability of the region to support even larger releases of juveniles planned for coming years. Hatchery released salmon now comprise 50 percent or more of all adults returning to common property fisheries in the Sound. In view of a growing controversy over apparent adverse interactions between hatchery and wild salmon stocks in Washington, Oregon and British Columbia, it seems appropriate to examine the question of carrying capacity as one means to assist with the continued enhancement and management of these vital commercial and subsistence resources in the Sound. The assessment presented here follows accepted ecological theory but is based on several untested assumptions. As a result, conclusions derived from the formulation are probably valid only as general guidelines and perhaps most useful as assertions to be formally examined under field and experimental conditions.

Parsons (1987) presents generalized carbon budgets for open ocean, shelf, fjord and estuarine ecological zones in the North Pacific. Because of its depth and oceanographic characteristics, Prince William Sound is best described as a complex fjord-type ecosystem (Schmidt, 1977). In the deep fjord environment a large percentage of the organic matter produced by phytoplankton is

utilized in the water column by pelagic consumers before it can settle to the sea bed.

Annual primary production in Port Valdez/Prince William Sound probably ranges between 150 and 200 g C m-2 y-1 (Goering et al., 1973). Primary producers are light-limited during the winter months, and following a dramatic spring phytoplankton bloom that usually peaks in April and May, the production of organic matter falls to lower levels under reduced nutrient supplies for the remainder of the summer and fall. A typical subarctic spring diatom community is replaced by small flagellates in mid summer as dissolved inorganic nutrients become depleted in the photic zone (Alexander and Chapman, 1980).

Zooplankton stocks in Prince William Sound are composed of both oceanic and neritic species (Cooney and Coyle, 1988). Coastal circulation patterns and long periods of wind-driven shelf convergence seed the region with open ocean populations during the spring and fall months. The copepods Neocalanus cristatus, N. plumchrus and Eucalanus bungii are indicators of intruding oceanic communities (Cooney, 1986, 1988, Coyle et al., 1990). These populations and Pseudocalanus spp. dominate the upper-layer zooplankton populations during the spring and early summer, March-May. Occasionally, Calanus marshallae adults and early stage copepodites are common during this period as well.

As the upper-layers begin to warm and freshen in late May and June, the oceanic zooplankton community is supplanted by a neritic assemblage characterized by late stage copepodites of Calanus marshallae, the smaller copepods Acartia, Centropages, Tortanus, Pseudocalanus, and the cladocerns Podon and Evadne. For juvenile salmon entering the Sound from hatcheries or natal streams, the composition and mass of forage fields changes substantially from April through June and early July.

Studies of juvenile salmon food webs in Prince William Sound implicate the importance of calanoid copepods (Cooney et al., 1981). While many other species are found in stomachs, the bulk of the mass is generally accounted for by the copepods although pteropods, insects (particularly for juvenile chum salmon) and other taxa are occasionally important.

The local hatcheries have adopted a practice of pen rearing fry during the spring until populations of Neocalanus, Calanus and Pseudocalanus have begun to reach seasonal highs, usually during late April and early May. At this time, most hatchery stocks are released into "optimal" feeding and (presumably) growth conditions. In contrast, wild fry emerge into the near-shore environment for roughly 2 months beginning in early April and continuing through the first week or so of June. Juvenile pink salmon apparently adopt a pelagic feeding behavior immediately, taking advantage of available zooplankton populations. Juvenile chum salmon appear to require a more epibenthic food web augmented by calanoid copepods and insects (Barnard, 1981). Young salmon are believed to be resident in the Sound from April through July and early August of each year.

Carrying Capacity

The productivity of marine ecosystems reflects the amounts

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and supply rates of dissolved inorganic nitrogen and silicon available to primary producers. In coastal waters, direct input of carbon from land sources may also be important. Seasonality in solar energy further modifies the magnitude and extent of the marine production cycle each year. With the exception of anoxic environments, most marine ecosystems are tightly coupled, with little carbon lost to burial in sediments.

In terrestrial ecosystems, the notion of carrying capacity refers to balances between plant production and herbivore consumption. "Over-grazing" typically leads to changes in soil stability and in the natural composition of plant stocks, followed by reductions in herbivore populations due to lowered reproductive rates and increased losses to natural mortality and predation. In the case of salmon ranching, carrying capacity denotes the ability of local receiving waters to accommodate additional consumers without adverse or other major changes in ecosystem dynamics.

It is believed that year-class strength in Pacific salmon populations is generally set during early ocean residence by predation (Parker, 1968, 1971; Healey, 1982; Hartt, 1980; Bax, 1983; Nickelson, 1986; Ricker, 1976; Foerster, 1968; Taylor, 1977; Walters et al, 1978; Holtby et al.,1990). Factors affecting the growth of juveniles at this time, such as temperature and food, are believed to mediate these important early losses to larger fishes and birds. Presumably, there are limits to the number of allocthonous consumers a natural system can absorb before competition forces measurable changes in biological structure and energy flow.

In his model of carbon flow between trophic levels in a generalized subarctic fjord ecosystem, Parsons (1987) follows accepted ecological practice in assigning values for biomass transfer efficiency between levels to estimate apex production in simple pelagic and detrital food webs. His choice of 10 percent transfer efficiency for fjords is derived from the earlier work of Cushing (1971) who demonstrated an inverse relationship between productivity and ecological transfer. While this choice is certainly subject to error, in reality it is the number of trophic exchanges leading to target apex predators that is by far the more important variable in formulations of this kind. Juvenile pink and chum salmon are almost entirely dependent on first-order consumers, meaning that only one, or at most two trophic steps are involved in the transfer of energy from phytoplankton to the young fish.

The analysis presented here uses information about the production of plankton communities in Prince William Sound to derive estimates for the production of potential salmon forage each year. A second analysis uses observations on the growth rates of surviving juveniles and their food to estimate the present demand being placed on fry forage populations each year.

Annual Herbivore Production

Adopting the fjord model of Parsons (1987) and the range in annual primary production reported by Goering et al. (1973), the total herbivore production is estimated to range between 13.8 and

18.4 g C m-2 y-1 in Prince William Sound. In this model (a generic 300 m deep fjord), a regression equation relating vertical carbon flux to depth (Suess, 1980) predicts 8 percent of the primary production will escape the water column to feed sea bed consumers while the remainder enters a pelagic food web. Converting herbivore carbon growth to wet weight (Beers, 1966) yields values of 204 to 273 g m-2 as the annual biomass production.

Prince William Sound has a surface area of approximately 8800 km2 or 8.8x10^9 m2 (Grant and Higgins, 1910). Multiplying the surface area of the Sound by the upper and lower estimates of the annual zooplankton wet weight production m-2 results in a over-all estimate of 1.8 to 2.5x10^12 g of forage available to all planktivores each year (Table 1). Assuming conservatively that 25 percent of this "herbivore" production is associated with macrozooplankton (Sambrotto and Lorenzen, 1987), between 4.5 and 6.0x10^11 g are available as food for fry and other planktivores.

Salmon Fry Forage Demand

The non-profit hatcheries in Prince William Sound are presently releasing about 700 million fry and smolts annually (most are pink salmon). Alaska Department of Fish and Game believes that wild stocks contribute another 500 million fry for a total of approximately 1.2 billion juveniles. Most of these young salmon utilize a pelagic food web during their early ocean residence.

Recent studies of post-emergent recaptured fry suggest that survivors of early ocean predation increase their body weight by at least 3 percent daily (Willette; unpublished). Both hatchery and wild fry enter marine waters at body weights of about 0.25 g. The fry are thought to reside in the Sound for 4 months or about 120 days. At an increase of 3.0 percent body weight per day, a survivor leaving the Sound after the period of summer residence will theoretically weigh about 9.1 g. Assuming this exponential increase in weight results from the ingestion of pelagic forage at a 50 percent gross growth efficiency (Wissmar and Simenstad, 1988), each survivor would have to consume at least 18.2 g live weight of zooplankton before leaving the region for shelf and open ocean feeding areas. If all the entering fry/smolts survived the 4-month near-shore period, the calculated demand on local forage stocks would be 21.8x10^9 g or about 2.2x10^10 g annually (Table 2).

The impact of fry feeding on pelagic herbivores and macrozooplankton stocks can be estimated by comparing the forage demand at several levels of growth with the available forage (Table 3). At growth rates of 3 to 4 percent of the body weight per day and using 150 g C m-2 y-1 , the fry apparently take 1.2 to 4.0 percent of the annual herbivore production and 5.7 to 16.1 percent of the macrozooplankton production.

A more accurate evaluation of fry feeding demand can be achieved if account is taken of fry losses to mortality during early ocean residence. Since 1978, the marine survival of hatchery released pink salmon has averaged about 5 percent. In contrast, the marine survival of wild pink salmon is thought to

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be only about 1 percent. Using an exponential model to calculate the instantaneous daily mortality rates for both populations yields losses to predators of 439 million and 390 million juveniles respectively for hatchery and wild fry populations over the 120 day period of early ocean residence. One estimate of the food consumed by non-survivors (829 million fry) can be obtained by assuming that the mortality occurs halfway through the 120 day interval when the fish are approximately 1.5 grams in size. The increase in weight of 1.25 g per fish requires the ingestion of 2.50 g of forage. Multiplying this amount by the number of fry failing to survive, predicts that those entering food webs consume approximately 9.6x10^8 g annually. The surviving 371 million fry (growing at 3 to 4 percent of their body weight daily) will ingest between 6.6x10^9 and 2.2x10^10 g (Table 4).

Under these more reasonable conditions, the impact of the fry on local forage resources becomes 0.4 to 1.6 percent of the total herbivore production and from 1.5 to 5.0 percent of the annual macrozooplankton production.

Discussion

The simplistic formulations presented here point to rather minimal "apparent" impact by present levels of wild and ocean-ranched salmon on zooplankton forage resources in Prince William Sound. Juvenile salmon consumption (corrected for early marine mortality) ranges between 0.4 and 1.6 percent of the total "herbivore" production and only 1.5 to 5.0 percent of the macrozooplankton annual growth. However, it must be remembered that these results are based on several key assumptions supported by few or no direct observations from the region.

The trophic model of Parsons (1987) assumes that a rather small percentage of the primary production (8%) escapes the water column and that the remainder is available to pelagic consumers. Cooney and Coyle (1988), using the equations of Suess (1980) and sediment trap data, report that up to 15 percent of the production in Port Valdez (230 m deep) can sink to feed benthic consumers in that location. Interannual variability in zooplankton standing stocks, associated with fluctuations in the transport of populations into and out of Prince William Sound, very likely influence the amounts of organic matter retained in pelagic food webs each year. Losses averaging 8 to 10% of the primary production to sinking each year seem reasonable in terms of observations elsewhere.

The model of Parsons adopts a 10% ecological transfer efficiency between primary and secondary producers based on published experimental results (Cushing, 1971). This standard approach is generally accepted with the understanding that the actual transfer may vary around this value by as much as a factor of 2.0. In the case of salmon fry, what is more important is that most feeding studies implicate first-order consumers (Cooney et al., 1981) as major prey items. This means that only one trophic step (rather than more) is usually involved in transferring organic matter from phytoplankton to the young fish.

The model applied here also assumes that the primary productivity of Prince William Sound will only vary between 150

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and 200 gC/m2/yr. Very few local measurements of production are available to support this contention through the years, although compared with other U.S. and Canadian fjords and Sounds, this level of production is well within reported limits (Cooney and Coyle, 1988).

Table 2 demonstrates that estimates of food consumption are very sensitive to the growth rates of the fry. The most recent studies of fry growth in Prince William Sound (Willette; unpublished) demonstrate absolute growth rates, determined from coded wire tags and otoliths, of 3-5 percent of the body weight per day. Assuming a value of 4 percent is probably representative of most conditions. However, until techniques become available (small-mesh purse seines and large surface trawls) to sample the larger more elusive fish, the degree to which growth rate determinations are biased by capture techniques will remain unknown. Given the average weight of adult pink salmon originating from central Alaska stocks reported by Rogers (1987), a daily instantaneous growth rate of 2.4 percent of the body weight applies over the 365 day ocean growth period. In actuality, this rate is expected to be higher during early ocean residence and lower in the late winter and spring of the return migration.

Since juvenile salmon are thought to be residents of the Sound for only four months, not all of the annual zooplankton production is available to them. However, because they enter the system during the peak of the annual production cycle, it is probably not unreasonable to assume that their feeding "window" encompasses at least 50 percent of the macrozooplankton production cycle, if not more.

Of even greater uncertainty is how much of the Sound the young salmon actually use for feeding purposes. Most observations indicate a variable period of shoreline/embayment dependency followed by a gradual movement into the deeper passages (Urquhart, 1979). It seems likely that something less than 100 percent of the Sound is actually used for feeding purposes. This potential limitation is further complicated by wind, tidal and density-driven upper-layer circulation patterns that may or may not replenish depleted near-shore zooplankton populations from deeper adjacent passages.

Finally, it is not known what portion of the water column can be utilized by juvenile salmon. If the young fish are restricted to the top few meters of the Sound, they will probably encounter a smaller percentage of the total zooplankton forage than if they can exploit the upper 20 or 30 m.

The degree to which these uncertainties inflate the the theoretical estimates of salmon fry impact on zooplankton forage resources in Prince William Sound is presently unknown. Questions raised above generally suggest a somewhat greater rather than lesser impact but the magnitude of error is difficult to judge without information about how the juveniles actually use the Sound as a nursery area and what portion of the pelagic consumer community is selected. Present studies in the region are designed to address these and other questions about the use of Prince William Sound by juvenile salmon. It seems important that answers to questions of resource partitioning be sought in

light of evolving enhancement plans for salmon in this region.

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Table 1. Theoretically derived estimates of secondary production (SP) and the production of macrozooplankton (SPM) derived from simple food chain dynamics associated with four levels of primary production (PP) in Prince William Sound, Alaska

PP gC/m2/yr	SP* gC/m2/yr	SP** g	SPM*** g
250	23.0	3.0x10^12	7.5x10^11
200	18.4	2.4x10^12	6.0x10^11
150	13.8	1.8x10^12	4.5x10^11
100	9.2	1.2x10^12	3.0x10^11

* Herbivore production assumed to be 0.1 PP (Parsons, 1986)

** Herbivore production in live weight for Prince William Sound

***Macrozooplankton production as 0.25 SP

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Table 2. Fry forage consumption as a function of growth rate over a 120 day period of early ocean residence in Prince William Sound, Alaska

Growth rate % body wt./day	Weight gain g	Food Consumed per fry, g	Total food* consumed
2	2.5	5.0	6.0x10^9
3	9.1	17.8	2.2x10^10
4	30.1	60.3	7.2x10^10
5	100.6	201.2	2.4x10^11

* assuming no mortality to fry during 120 day period

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Table 3. Estimated impact of fry feeding on zooplankton production in Prince William Sound, Alaska derived from two levels of primary production

Fry Growth % body wt./day	Total Consumption (TC), g	TC/SP	TC/SPM
A. 150 gC/m2/yr			
2	6.0x10^9	0.003	0.013
3	2.1x10^10	0.012	0.047
4	7.2x10^10	0.040	0.161
5	2.4x10^11	0.134	0.537
B. 200 gC/m2/yr PP			
2	6.0x10^9	0.003	0.010
3	2.1x10^10	0.009	0.036
4	7.2x10^10	0.030	0.121
5	2.4x10^11	0.100	0.403

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Table 4. Estimated impact of salmon fry feeding on zooplankton stocks in Prince William Sound accounting for losses to predation and natural mortality during the 120 day residence period

Fry	Fry Growth % body wt./day	Total Consumption, g	TC/SP	TC/SPM
371 million surviving	3	6.6x10^9	0.004	0.015
	4	2.2x10^10	0.016	0.050
	5	7.5x10^10	0.041	0.166
829 million not-surviving	2*	9.6x10^8	0.0003	0.0013

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* non-survivors assumed to grow at 2 percent or less of their body weight per day. Mortality assumed to occur half-way through the 120 day residence period

AGENDA
Workshop on the
"Biological Interactions of Natural and Enhanced
Stocks of Salmon in Alaska"

Saturday, November 9

Participants arrive during the day.

5:30-7:00 pm Welcoming reception, at the Powder House (transportation provided -- please meet in the lobby of the Reluctant Fisherman between 5:25 and 5:45 pm)

All the plenary meetings are held in the Masonic Hall (located at the north end of First Street). The daily schedule is as follows:

7:45 - 8:30 a.m.	Continental Breakfast (at the Masonic Hall)
8:30 - 10:00 a.m.	First Morning Session
10:00 - 10:30 a.m.	Coffee Break
10:30 - 12:00 noon	Second Morning Session
1:30 - 3:00 p.m.	First Afternoon Session
3:00 - 3:30 p.m.	Coffee Break
3:30 - 5:00 p.m.	Second Afternoon Session

The public is invited to all sessions on Sunday, Monday and Friday.

Sunday, November 10 *Open to the public*
First Morning Session - 8:30-10:00 a.m.

Opening remarks:

1. G.L. Thomas, Director Prince William Sound Science Center
2. Goals of the Conference - Ole Mathisen, Univ. of Alaska-Juneau
3. Prince William Sound Aquaculture Corporation - John McMullen, President
4. State Genetic Policy - Jim Seeb, Alaska Dept. of Fish & Game

Session 1 -- Ocean carrying capacity
10:30-12:00 Session Chair: (TBA)

1. *A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.* R. Ted Cooney, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks
2. *Density dependent changes in chum salmon, Oncorhynchus keta, returning to Iwate Prefecture, Japan.* Hitoshi Ida, Kitasato University School of Fisheries Sciences, Sanriku-cho, Kesen-gun, Japan

3. *Factors affecting marine growth of Bristol Bay sockeye salmon.* Don Rogers, Fisheries Research Institute, University of Washington, Seattle, Washington

4. *Interaction in natural carrying capacity limitations for natural and enhanced stocks of salmon.* Percy Washington, GAIA NW, Inc., Seattle, Washington

5. *The carrying capacity of the North Pacific Ocean.* W.G. Pearcy, Oregon State University, Corvallis (Summary)

Session 2 -- ***Management of mixed stocks***
1:30-3:00 p.m. Session Chair: (TBA)

1. *Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska.* Doug Eggers, Chief Fisheries Scientist, Alaska Department of Fish & Game, Juneau, Alaska

2. *Management of mixed enhanced and wild salmonids in British Columbia.* Don Bailey, Salmon Enhancement Division, Department of Fisheries and Ocean, Vancouver, Canada

3. *Gene frequencies, risk assessment and the management of hatchery production of Pacific Salmon.* Jim Seeb, Alaska Department of Fish & Game, Anchorage, Alaska

Session 3 -- Summary and general discussion
3:30-4:30 p.m. Session Chair: (TBA)

Evening Seafood dinner at the Reluctant Fisherman
Social hour, 6:30 p.m.; Dinner, 7 p.m.

Monday, November 11 *Open to the public*

Session 4 -- Basic Genetic Structure
8:30-10 am Session Chair: Jim Seeb

1. *Conservation of genetic diversity in salmonid fishes: why, what and how.* F.W. Allendorf, Division of Biological Sciences, Missoula, Montana

2. *The predictive value of stream distances for estimating genetic relationship in salmonid species.* Fred Utter, National Oceanic and Atmospheric Administration (NOAA), Seattle, Washington

3. *Population genetic structure of chum salmon: identification of wild and hatchery fish in mixed fisheries.* Lisa Seeb, Alaska Department of Fish & Game, Anchorage, Alaska

4. *The importance of fine genetic structures in natural populations.* Tony Gharrett, School of Fisheries and Ocean Science, University of Alaska, Juneau, Alaska

Session 4 continued
10:30-12:00

5. *Quantitative genetic variation of life history traits in pink salmon.* William Smoker, School of Fisheries and Ocean Science, University of Alaska, Juneau, Alaska

6. *Genetic stock identification of Yukon River chum and chinook salmon.* Richard Wilmot, U.S. Fish & Wildlife Service, Anchorage, Alaska

7. *Genetic relationships among Pacific salmon of the Bristol Bay area of Alaska.* Rebecca Everett, U.S. Fish & Wildlife Service, Anchorage, Alaska

Session 5 -- Straying
1:30 - 2:00 pm Session Chair: TBA

1. *Homing, straying and the interaction between wild and enhanced stocks of salmon.* T.P. Quinn, Fisheries Research Institute, University of Washington, Seattle, Washington

2. *Do culture conditions of hatchery reared salmon affect return and straying of adults?* Sven Ebbesson (paper only)

Session 6 -- Long Term Case Histories
2:00-3:00 pm Session Chair: TBA

1. *Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.* Tor Heggberget, NINA, Norsk Institutt for Naturforskning, Trondheim, Norway

2. *The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers.* Torleif Eriksson, Swedish University of Agricultural Sciences, Department of Aquaculture, Umea, Sweden

Session 6 continued
3:30-5 pm

3. *The perpetual oversight of hatchery programs.* Ernest Brannon, University of Idaho, Moscow, Idaho

4. *The S[illegible]xperience in the field of salmon interactions.* Mikhail Glubokovsky, Institute of Marine [illegible]gy, Far East Branch, Vladivostok, USSR

5. General discussion

Tuesday, November 12

Field trip to Wally Norenberg Hatchery at Esther Island (western Prince William Sound) -- *Weather dependent, this may be delayed until Wednesday.*

Departure time for field trip: 9:15 am - Please meet in hotel lobby.

Wednesday, November 13

Session 7 -- Interactions in Prince William Sound
8:30-10 am Session Chair: TBA

1. *Historical production of wild and enhanced stocks of pink salmon in Prince William Sound.* Sam Sharr, Alaska Department of Fish & Game, Cordova, Alaska

2. *(Title TBA)* Jeff Olsen, Operations Manager, Prince William Sound Aquaculture Corporation, Cordova, Alaska

Session 7 continued
10:30-12 noon -- ***Interactions in Prince William Sound***

Session 8 -- Interactions in Southeast Alaska
1:30-3 pm Session Chair: Ole Mathisen

1. *Southeast Alaska Chinook; Fisheries, management, enhancement, wild stocks and treaties.* William Heard, National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, Alaska

2. *An Overview of the Pink, Chum and Coho Enhancement programs in Southeast Alaska.* Don Amend, Southern Southeast Aquaculture Association, Ketchikan, Alaska

Session 8 continued
3:30-5 pm -- ***Interactions - General discussion***

Thursday, November 14

Session 9 -- Interactions regarding other species, especially sockeye
8:30-10 am Session Chair: TBA

Session 9 continued
10:30-12 Noon

Session 10 -- The Working Party: Writing sessions divided into sub-groups
1:30-5:00 pm Session Chairs in charge of each group

Friday, November 15 *Open to the public*
Session 11 Concluding Session
Session Chair: Gary Thomas

8:30-10 am Session leaders will present a short discussion of the findings of their working group followed by an open discussion session and approval of reports and documents.

10:30-noon Open discussion session continues.

Afternoon Departures

REPORT TO THE BOARD OF DIRECTORS

September 20-21, 1991: PWSAC Meeting

Update of Cooperative Fisheries and Oceanographic Studies (CFOS) in Prince William Sound, Alaska

In January 1990, the Alaska Sea Grant College Program provided funding to help establish a consortium investigation of salmon production responses to oceanographic conditions affecting fry/smolts during early ocean residence. The study was joined by ADF&G, PWSAC and VFDA as co-investigators. Since that time, CFOS has established a systematic program of oceanographic monitoring and experimental studies to determine how year-to-year changes in coastal ocean climate and fry food stocks influence the production of pink and chum salmon in the Sound. This study concluded its second field season this year.

CFOS studies are guided by a growing body of scientific evidence suggesting the number of adults returning through fisheries to hatcheries and natal streams each year is determined primarily by predation during early ocean residence -- the first two to four months at sea. Conditions of food and temperature that influence the growth rates of the fry/smolts apparently mediate losses at this time. Since this critical phase is spent in the "near-shore/coastal marine environment", growth conditions can be studied in detail locally without the need for costly oceanographic expeditions to the open ocean.

The primary goal of this study is to quantitatively describe the relationships between observed levels of salmon production and variables know to affect the growth of juveniles in the coastal ocean. This information is expected to significantly enhance local forecasting procedures and provide further means to optimize the production of hatchery-released and wild stocks of salmon in the Sound. Prior studies of the oceanography of the the Gulf of Alaska have established an understanding of cyclic temperature fluctuations and have also documented large year-to-year changes in upper-layer zooplankton populations. The most recent observations support a prediction of a return to cooler temperatures for the next 5-8 years. On the basis of what is presently understood about temperature influences on salmon production, this decline in temperature will quite likely be expressed in reduced wild and hatchery production. Should this be the case, hatchery stocks of pink and chum salmon may have to carry the fisheries through the upcoming inclement oceanographic period.

Experimental studies to date include descriptions of the growth ecology of large calanoid copepod populations and their energetic content, and of the potential for using satellite-sensed temperature fields to assist with forecasting and enhancement programs. The large calanoids form a substantial and important food resource for first feeding wild and hatchery fry in the region. In this regard, understanding the time-phasing and abundance of these important food organisms in relation to variable oceanographic factors is expected to help further refine release strategies designed to optimize production under different conditions of food and temperature. Additional experimental studies involve direct measurements of fry growth using coded-wire tagged fry and their otoliths. These important studies are needed to confirm the assertions that growth rate is the variable that modulates losses to predators each year.

CFOS information is also expected to be crucial in determining if, and to what extent, hatchery stocks may be interacting with wild salmon populations in Prince William Sound. Questions of resource partitioning, genetic alteration and carrying capacity are being raised by some who see hatchery production as potentially threatening to the health of wild stocks in the region. In the interest of the fishing industry, these questions must be rigorously addressed by good science immediately. While there seems to be a case for some negative interactions in Washington, Oregon and British Columbia, there is no reason to believe that these findings apply unconditionally to Alaskan mixed stocks. An upcoming workshop on this matter is scheduled for this fall in Cordova. I have been asked to participate in this workshop and I intend to present a theoretical assessment of the carrying capacity of the Sound for juvenile salmon at that time.

The present CFOS study is designed to continue through December 1994. There is a chance that it could be extended one additional year if the results warrant and the co-investigators request a continuance from the Alaska Sea Grant College Program. This coming year, CFOS expects to add a new component to study juvenile chum salmon. The chum investigation will attempt to determine why this species has failed to respond as positively to culture technique as have pink salmon. The results of the chum study are expected to help the corporation modify (if necessary) its rearing and release procedures to maximize chum production in the years to come.

I wish to thank the corporation for its generous support of CFOS studies over the past two years. Without the cooperation of hatchery managers, their staff and the front office, the study could not have been pursued. As it is, CFOS is one of the most comprehensive fisheries oceanographic investigations in the entire country. The addition of a modern satellite-linked oceanographic buoy system this fall will add the final ingredient to what may become a pilot program for future management and enhancement of salmon stocks throughout Alaska. It is my recommendation to the board that this cooperative tie to the University and Fish and Game be exploited to its maximum potential over the next four years. As a board member, I will do what I can to see that this potential is realized.

Respectfully submitted,

R. Ted Cooney

R. Ted Cooney
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

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University of Alaska Fairbanks

Japan are they a good model?
use all the same fish stocks - genetic strain
go their identities where they feed the most
concentrating in a habitat where they
can deplete fish stocks.

Cooney - PWS -
\ smaller fish also present in low return years.
marine survival rates @ the same even in higher years

Bristol Bay - always had smaller fish in hi return years
reduce

PWS
average 1.6 kg wt
90 1.4
91 1.1

historical data - fish are smaller when runs are larger -
B Bay

clearly - is shortage of food, but where does it occur?
is it local or in big ocean
\ related to avg of schools of
fry a returning
schools.

also lower water temp in Pacific

when does growth modification occur - early? late? or
current growth year

in SE - no hatchery pinks still ↓ in size
also reduction in Sound/Inlet where no hatchery fish.

Zooplankton/fry stocks - fluctuate greatly year to year

monitor growth conditions - esp. in near shore areas
plankton watch
temp watch
predator watch

~~Genetics~~ Conservation

Goal - maintain existing genetic diversity within & between wild populations in order to sustain productivity of both wild and enhanced stocks.

Straying - can we model
- no sign
- what is significant - affects future productivity
- also disease - wipe out populations.

Disease
VHS in WA
disease in Norway.

1. request from Steve McGee
   list of all fish transpt permit applications
   everyone's recommendation final disposition

2. chart showing
   current hatchery production
   — what is planned and permitted
   by region, and totals
   by species.

3. talk to Ray Hilborn, @ Canada + U Washington

4. Ted Perry - salmon assessment in Canada.

wild production - temp. dependent — ocean is cooling, will ↓ wild stocks

hatcheries - much higher return 10-20%, chinook - 40-60%
wild pinks - 4-5% return

Carrying capacity
density dependent growth - large schools of fish - early + late
modify food supply

- fish getting smaller
- impair reproductive ability
- ↑ predation
- more difficult to market

concern - hatchery fish eating food fish
not real

DRAFT
Biological Interactions of
Natural and enhanced fish
Stocks in Alaska--Workshop
14Oct1991

INTERACTIONS AND ENVIRONMENTAL CARRYING CAPACITY LIMITATIONS OF NATURAL AND ARTIFICIAL STOCKS OF SALMONIDS

PERCY M. WASHINGTON

"Enhancement" as a technology has become synonymous with restoration, supplementation, or augmentation of depleted naturally reproducing runs of salmonids. In theory, available technology allows production, under controlled artificial conditions of almost unlimited amounts of salmonids scheduled to mitigate losses of smolts formerly produced in natural habitats that were altered or destroyed by human activities such as dams, logging, road building, mining, agriculture, rechannelization. Hatcheries were conceptually to replace spawning and the various rearing habitat requirements of salmonid and prey species. The technology evolved to reduce the high probability of mortality during freshwater life history periods of anadromous salmonids. Stocks were homogenized to produce a more easily handled, optimized single stock with advantages (to managers and hatchery operators) such as short run timing, smaller size for ease of handling, and docile behavior which improved within facility survival. Run timings (primary stock differentiation) were truncated, and growth rates of individuals within the artificial populations were increased for cost and space efficiency.

Short pulsed hatchery runs provide the basis for net fisheries that subsequently become the only efficient means of harvesting massive surplusses created by the hatchery system; 3-5% of hatchery stocks are required for population reproduction, anything less than a 95% harvest results in waste. Other harvest methods and uses that were viable historically are traps and sport harvest, natural mortality, and escapement; escapement and natural mortality were two uses of the resource which lost out due to their lack of obvious economic value. Traps were outlawed to provide increased economic opportunities; more labor intensive net fisheries. Sport fisheries represent comparitively limited levels of efficiency and effort, and are incapable of harvesting significant portions of a hatchery run in the terminal areas due to the short length of the run pulse; sport fisheries represent only a nominal portion of the total catch. Net "mop-up" fisheries are efficient and sufficient in quantity to reduce runs over night from surplus to minimal escapement levels that support only hatchery runs; levels that have no sport fish appeal where catch per effort isn't worth the effort. Some hatchery stocks have evolved that stop feeding in terminal areas; only those that didn't hang arround to feed and get caught by nets survived.

As a management tool, artificial production facilities

provide a means, at least theoretically, of producing sustainable yields of salmonids up to the carrying capacity of the ocean. As is the case in freshwater habitats, the actual oceanic yield potential is greatly increased when time, space and niche separations are observed by species and races of salmonids, as well as their propagators. In the late 1970's, the Oregon Department of Fish and Wildlife (ODFW) presented coastal upwelling and coho densities as the hypothesis for the reduction in coho production along the coast of southern Washington, Oregon, and northern California; the Oregon Production Index Area -- OPI. Emperical formulas, "Spawner/Recruit Curves" after Ricker (1972) (McGee, 1979), correlations with shrimp and crab production (McIntyre, 1978), and just about anything else were used to make the point that the ocean was too full of coho; especially during periods of low upwelling. At the time my studies of the problem as part of my dissertation project. Since everyone else was studing "ocean density" as the prime factor, I decided to break new trail and analyze existing data to determine survival at various life stanzas between the hatchery, estuary, ocean, and adult returns. I estimated survival into the ocean by use of the sex dicotomy method after Doug Chapman. To my dismay, there seemed to be something wrong with the model or the data as the survival to be an order of magnitude less than what ODFW reported (Gunzolus, 1978). I tested assumptions and looked for new methods of determining survival at the various stanzas, hitting upon size dicotomy at the estuary. Using this method, I demonstrated more than 75% mortality between the hatchery and the estuary; which was later demonstrated to be the result of poor quality hatchery releases and management practices (Washington, 1982). Subsequently, Bonneville Power Administration (BPA) Fish and Wildlife Branch noted that 75% of those fish reaching the estuary had Bacterial Kidney Disease resulting in an additional mortality (Personal Communication, Dr. Gerald Bouck) which reduced the population to less than 8% of it's original number at release.

Commercial fishermen observed and fished in massive shoals of coho of the Oregon coast. My observations during Alaska field studies in the 1960's and 70's were that wild coho did not school. Observations also suggest that hatchery coho are induced by domestication/selection processes to school. Wild coho were never encountered at sea nor in terminal areas in greater congregations than ones and twos. A high probability also exists that large numbers of the massive simultaneous hatchery releases of a single stock may migrate to the same spot in the ocean at the same time and result in production limiting densities; a problem that does not seem to exist among wild coho populations.

Genetic selection and feeding induced increases in growth rates of salmonids in hatcheries may result in decreased ultimate size potential of returning adults; this is the basis of Donaldson's work on hatchery salmon and trout production in the 1950's through 1970's, and also results from fishery gear selection. Decreased adult biomass potential results where there is an increase in precociousness. Increasing freshwater growth rates to achieve larger emigrant sizes and early release timings de-

creases the numbers of individuals reaching ultimate size potentials within the population, and reduced egg quantities and quality.

Fisheries based upon surplusses from the enhancement of resources consistently foster the over harvest of naturally reproduced stocks. On the surface, this was accomplished with no apparent damage to the artificial stocks. Indications are, however, that adults returning to hatcheries are fewer and smaller in size; only small fish can escape harvest by the size selective gears used (Becker, 1967). The historical trend of increased amounts of less efficient fishing gears, and the movement of fisheries farther from terminal areas, resulted in the selective capture of the older/larger individuals resulting from both natural and artificial production. This resulted in reduced reproductive potential in wild stocks. The reduction was a direct result of qualitative and quantitative losses of gametes associated with average individual size reductions; phenomena that also reduced spawner and progeny success. These exacerbated fishery management problems, ultimately resulting in the requisite use of artificial propagation of salmonids to maintain harvests; current best described as "put and take" salmon fisheries. In elementary fishery courses we were taught that smaller females produce smaller and fewer eggs. Followed to its logical conclusion, fewer, smaller females returning to hatcheries result in the use of all available gametes (male and female), fry and fingerlings. In combination with probable reductions in female escapement and average size in a poorly regulated fishery, gamete limited production of hatchery releases will result.

Unfortunately, most all agencies have limited management options by systematically destroying that necessary to produce large numbers of salmonids naturally; rivers were dammed, forests cut, and the seemingly endless wealth of natural resources gave rise to population centers that required agricultural products; all were at the center of habitat loss. Habitat is limiting, and limited amounts of habitat produce limited numbers of fish; limited habitat is, therefore, population limiting. Artificial production is but a tool. In its current context and use as a monoculture system, it ultimately limits production and production potential. The lessons of history should instruct us to optimize production from natural and artificially produced stocks.

A few years ago, I was present when Washington fishery managers expressed to a legislative hearing the inability to successfully manage wild and artificial stocks in the same watershed. Agency efforts at enhancing production always seems to decrease production measurably in a water ship. The natural environment is capable of producing large amounts of fish biomass in relatively sterile surroundings by simply adding nutrients from the decayed bodies of dead adult anadromous fish. The hint in this case is that the dynamics of niche, spatial and temporal separation results in a substantial increase in biomass production. If we are to have both naturally and artificially produced

salmonids, limiting competition within and among species for limited environmental resources in the freshwater environment is a must.

Artificially produced fish feed on food items in mid to surface waters (Graves 1983; Beauchamp, 1989). Wild chinook, coho, and various trout feed near bottom on bottom organisms in their various preferred habitats. In effect, artificial fish of all species produced by current methods and released as pre-smolts are only capable of competing in the freshwater "pelagic" niche for the limited amount of food available. This is particularly important in lacustriane habitats that serve as habitat for naturally reproduced sockeye stocks. Under these circumstances, artificial produced species graze down all food organisms within size ranges that efficient for capture then starve; usually well before any numbers learn to feed on bottom organisms. Species that naturally feed in the midwater/pelagic niche suffer reduced growth as a consequence (Graves, 1983; Beauchamp 198).

The issue for fishery managers of size at, and release timing continues to be an interesting one. In the 1950's and early 1960's relatively small numbers of salmonids released relatively small in size and released three to six months earlier than todays releases produced greater survival rates to adult than very large releases of very large sized salmonids released during and after the observed smolt migration periods. The question of what constitutes a smolt continues to be known only to the smolts in spite of years of research to discover the secrets of this metamorphosis. This is a very interesting academic question and basic research problem, but the fact is that it is only important for the fish to be able to determine the proper time to emigrate and that they be allowed to emigrate at will. In 1979, I coined the term "volitional release" as a means of expressing the idea of fish being able to come and go at will from artificial ponds. This concept was a solution to problems associated with discovering the appropriate release time for artificial ponds stocked with salmon of mixed stock origins and varied individual emigration timings.

The majority of "lower 48" artificial production releases continue to be into river systems; superimposing them upon wild stocks at any number of several critical life stages. Numerous observers have observed that large portions of salmonid releases have been slow to emigrate or never emigrate (Royal, 1973; Wagner 1976). Residual releases may become competitors or predators of wild fingerlings or fry salmonids. Even worse, residuals seem to attract and support predator populations; for example squaw fish and cormorants.

For reasons never satisfactorily explained, salmonids have been planted for decades in upstream areas without a full understanding of the instream ecological requirements of the released salmonids, a knowledge of what resources these released salmonids are being superimposed upon, or a concern for the ecological devastation caused by these practices. The massive releases of

non-smolt salmonids in lakes and streams probably finished, albeit unwittingly, what over fishing, dams, and other manifestations of civilization could not. While one resource agency or division of that agency carefully husbanded a wild resource, another thwarted that effort by planting a competing or predator species in that habitat, or allowed a harvest that is at cross purposes. Enormous amounts of salmonid producing habitat was lost as the result of policies and programs which may fit one need at the expense of others. For example, the effects of lake screening programs meant to discourage catchable rainbow trout plants from emigrating have negatively impacted coho, cutthroat trout, dolly varden char, sockeye salmon, white fish species, and anadromous rainbow populations in numerous lowland lakes and streams. On the other hand, the planting of non-smolt coho in Western streams have resulted in reduced production of salmonid biomass, and in cases the loss of naturally reproducing salmonid populations through biological extinction.

Numerous negative examples of the effects of monocultural techniques in artificial enhanced river systems are available. A paramount example may have been the Columbia River coho salmon experience. During the 1970's, coho of the same genetic stock were released on the same date from 19 or more sites, entered the ocean within a few weeks of each other, and tag data from those releases indicate that most utilized Pacific waters from south of Grays Harbor to Northern California. Prior to the preeminence of artificial stocks in the Columbia, mark and tag data indicated that wild stocks contributed primarily to Washington coastal fisheries and were found in the Gulf of Alaska.

It is important that we begin to practice what we preach with regard to interception fisheries. Fisheries that preclude the management of salmonids on a stock basis should be terminated before they result in the biological extinction of wild stocks and damage artificial stocks. Wild and artificial adult stocks, further, must be identifiable, and spatially and temporally separated in terminal areas; especially where harvest is by dead fish fisheries such as gillnets and seines. Returning adults of artificial origin probably mix with wild salmon adults in off shore and terminal areas. Questions of harvest rates are usually determined to the determine of wild stocks which require 10 or more times the level of escapement than do artificial stocks to remain viable.

To recapitulate, the realities are that artificial propagation based policy has served to reduced stock genetic diversity, negatively manipulated downward the size and age of returning adults, provided a convenient excuse for the worse possible resource use practices, and had profoundly negative impacts upon wild stocks. It provided a rationale because of which critical rearing habitat was not protected. Naturally reproducing stocks were inevitably over harvested in mixed stock offshore and terminal fisheries, and escapements were reduced to below sustainable yield levels or worse yet, to economic extinction. The average size of individuals in stocks were decreased resulting in

reduced reproductive potential and, ultimately, reduced production.

In conclusion, the use of artificial propagation as a mitigative tool continues to have enormous potential. The historical record dictates that the "success yardstick" of the programs which used this tool be measured in terms of personal financial gains, fish industry employment, salmon landings over a prolonged period, pounds of artificially produced salmonids released, and wild run extinctions. The negative impacts to fishery resources iterated above make this a more bitter than sweet story.

DRAFT - UNFINISHED MANUSCRIPT

Homing, Straying and the Interaction Between Wild and Hatchery-Produced Salmon

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Abstract

This paper reviews studies on the patterns of straying of adult salmonids from their river or hatchery of origin, with an emphasis on Pacific salmon. The prevalence of straying varies greatly among populations. In general, introduced populations and salmon whose rearing history involves displacement or changes in water source may stray more than native stock and those reared and released on-site. Normal hatchery practices do not necessarily increase the tendency of salmon to stray, although evidence indicates that this may occur. While a generalized estimate of the proportion of salmon that stray would be useful, none seems appropriate because rivers and hatcheries vary so greatly in their tendency to produce and attract strays. There is evidence that the offspring of hatchery produced salmon may be less viable than those from local wild fish, hence straying between hatcheries and spawning grounds is cause for concern. Whether or not strays actually affect local gene pools depends not only on the prevalence of straying but on the degree of assortative mating and differential survival between populations. At present, fundamental gaps in our understanding of the genetic and environmental factors influencing straying hinder accurate prediction of the levels and consequences of straying.

Introduction

Homing to the natal site for reproduction is characteristic of salmonid fishes (Quinn 1990) but is has long been known that some individuals stray and spawn elsewhere. Straying is important for salmonids because it leads to the colonization of new habitat (Milner 1987; Milner and Bailey 1989) and avoidance of unfavorable local conditions (Lucas 1985; Leider 1989). However, research has revealed a wide variety of genetic differences among populations within species (see reviews by Ricker 1972; Saunders 1981; Taylor in press). Such differentiation presumably results from the scarcity of strays and/or their high mortality rate, relative to locally adapted salmon. The preservation of indigenous populations is one objective of salmon management (Wright 1981; McDonald 1981), in part because they are often more productive than transplanted populations (Ricker 1972; McIntyre 1984; Reisenbichler 1988).

Hatcheries differ from rivers in many respects and it is not surprising that genetic differences between hatchery and wild salmonids arise (e.g., Skaala et al. 1990; Swain and Riddell 1990; Johnsson and Abrahams 1991). To the extent that these genetic differences result in reduced fitness in the wild (Reisenbichler and McIntyre 1977; Chilcote et al. 1986), the straying of hatchery-produced salmon to interbreed with wild fish is cause for concern (Thorpe 1986; Barbat-Leterrier et al. 1989). Moreover, if the disparity in abundance between wild and hatchery-origin salmon is great, the presence of strays may frustrate efforts to correctly estimate population sizes. This paper is structured around a series of questions regarding homing to indicate the state of our understanding of this phenomenon. It concludes with recommended areas of future research to help determine the importance of straying in the interaction between wild and hatchery-produced salmon.

What is Straying?

Straying is the migration of mature individuals to spawn in a stream other than the one where they originated. The spatial scale implied by "where they originated" is vague. The management unit may be the stretch of coast, inlet or watershed. The extent to which wild salmon return to the tributary or reach within a tributary where they were spawned is not known. However, experiments have indicated that salmon released as smolts in sections of a river are more likely to return to that section than other sections (Wagner 1969; Cramer 1981).

From the standpoint of migration and orientation, a salmon strays if ascends a non-natal river and does not subsequently make its way to its natal river. However, if the fish enters a hatchery, it is seldom given the chance to retreat, so there is some question as to whether "strays" entering hatcheries would have eventually left.

When hatcheries rear salmon for a period of time and then "outplant" them (e.g., Nickelson et al. 1986), it is not clear whether "home" is the hatchery of origin or the stream of release. Similarly, when salmon are trucked around long stretches of the Columbia or Sacremento rivers (Ebel et al. 1973; Slatick et al. 1975; Sholes and Hallock 1979), is "home" the hatchery or the release site?

What proportion of naturally produced salmon stray?

Among the earliest large-scale studies of homing was Foerster's work at Cultus Lake, B.C. (summarized in Foerster 1968). All the sockeye salmon (Oncorhynchus nerka) smolts leaving the lake in 1931 and 1936 were fin-clipped. Marked adults comprised 99.4 and 98.5% of the returning adults of the appropriate age groups, indicating that very few sockeye from other Fraser River populations entered the lake. The vast majority of sockeye must pass Cultus Lake to return to their natal locations, so the absence of strays into the lake was noteworthy. However, there was no record of the number of marked Cultus Lake sockeye straying from the lake. Patterns of parasite prevalence and protein polymorphisms (Quinn et al. 1987) indicated that other sockeye salmon populations seldom strayed between lakes. Life history differences among populations within lake systems imply that homing to spawning areas within lakes is probably precise as well (e.g., Blair 1989).

A marking study of chum salmon, O. keta, on Hokkaido, Japan revealed that 97.8% of the 275 in-river recoveries were in the river of origin and the rest were found in nearby rivers (Sakano 1960, in Sano 1966). MacQuarrie and Bailey (1980) reported that 5.4 and 5.2% of the chum salmon fry produced in artificial incubation facilities on Thornton Creek strayed to Salmon Creek, B.C. in 1979 and 1980, respectively.

There is a widely held notion that pink salmon, O. gorbuscha, are more prone to stray than other Pacific salmon species. This was supported by the recolonization of Sashin Creek, Alaska after deliberate extermination of the even-year cycle (Merrell 1962) and the recolonization of the upper Fraser River by pink salmon after the rock slide at Hell's Gate (Vernon 1962). Parker (1967) also reported "... substantial straying within a fairly large 'home' area..." Finally, the rapid colonization of the Great Lakes by pink salmon after accidental introduction (Kwain and Lawrie 1981) and the White and Barents seas after introduction to the Kola Peninsula (Bakshtansky 1980) implies extensive straying. However, studies reviewed by Lister et al. (1981) revealed no particular tendency to stray and Gharrett (1985) reported that "no straying was observed from the genetically marked Auke Creek population into the unmarked Waydelich Creek implying accurate homing to stream of origin." I have been unable to locate a comprehensive study of straying by wild pink salmon populations, hence the conclusion that they stray more commonly than the other salmon seems premature.

There is both practical and theoretical interest in comparing straying prevalences among species (Quinn 1984). The long-term study by Shapavalov and Taft (1954) at Scott and Waddell creeks in California revealed that coho salmon, O. kisutch strayed between the creeks much more frequently than did steelhead, O. mykiss (15 and 27% vs. 2 and 3%). Unfortunately, there does not seem to have been another such study on wild populations of more than one salmon species in the same rivers and there is generally little data on straying by wild salmon. There seems to be considerable variation in straying prevalence among rivers, as several Vancouver Island coho salmon populations have much lower incidence of straying that Shapovalov and Taft (1954) reported (Labelle 1990).

In addition to studies of the distribution of adults that had been marked as juveniles, a number of experiments have assessed the fidelity of marked adults displaced from their spawning stream (presumed to be their home river). In general, the great majority of recoveries are in the river where the salmon were first captured (e.g., Hartman and Raleigh 1964). Variation in the proportion of displaced salmon returning may be related to site-specific characteristics (McCart 1970; Blair and Quinn 1991) or water flow at the time of the experiment (Helle 1966).

In general, there are so few comprehensive studies of straying by naturally produced salmon and there is so much variation in straying within species that interspecific comparisons are unwarranted. A general estimate is that 3-5% of the salmon produced in a river that survive to adulthood may spawn elsewhere but this probably overestimates straying in many cases.

Do salmon from enhancement facilities stray more commonly than naturally produced salmon?

Juvenile salmon from enhancement facilities are often marked as part of efforts to evaluate their marine survival and distribution, hence most data on homing and straying are from enhanced populations. In most cases there is no comparable tagging effort on naturally produced salmon in the same river, so it is not possible to determine if the enhancement facility influenced the proportion of salmon straying. However, two recent studies provide information on this question. Labelle (1990) tagged large numbers of coho salmon from several streams on the east side of Vancouver Island, B.C., including the Quinsam River, in which naturally produced, hatchery outplants (termed "colonization") and hatchery produced coho salmon were marked. There was no significant difference in the proportion of strays among the groups (Table 2). On the other hand, McIsaac's (1990) study of Lewis River, Washington fall chinook salmon, O. tshawytscha, indicated that even a brief period of hatchery rearing increased the proportion of strays, relative to naturally produced salmon from the same population (Table 3).

Are there spatial and temporal patterns of straying?

Given that some salmon stray, it would be useful to know whether they tend to stray to rivers below their origin (as might be expected if exhaustion influenced straying) and whether they tend to enter rivers or hatcheries with certain characteristics. Such information has been difficult to acquire owing to the difficulties of surveying non-natal rivers in an extensive and unbiased manner. Studies in which seaward migrants were fin-clipped seldom surveyed more than a few sites near the release location. However, widespread use of the coded wire tag (cwt) in hatcheries and selected rivers has presented the opportunity to study straying over large spatial scales. These tags are injected into the smolt's cranium and the presence of the tag is signalled by excision of the adipose fin. The primary purpose of such tagging studies is generally to estimate the marine distribution and survival of stocks or experimental groups. However, tags recovered from terminal fisheries, hatcheries and spawning grounds also provide information on straying.

Analysis of data on spring chinook salmon released from the Cowlitz River Salmon Hatchery indicated that most (98.6%) of the returning salmon ascended the Cowlitz River (Quinn and Fresh 1984). However, most of the strays went upstream beyond the Cowlitz River and 76.6% (446) of the estimated 582 strays were recovered in the Lewis River. This is more than four times as many as strayed to the Kalama River (108, 18.6%), even though the Kalama River is only 9 km upriver from the Cowlitz and the Lewis River is 30 km upriver of the Cowlitz.

More thorough analysis of five populations of fall chinook salmon on the Columbia River below Bonneville Dam revealed considerable variation among hatcheries in the tendency of salmon to stray, ranging from 9.9 to 27.5% (Quinn et al. 1991). More dramatic, however, was the variation in attractiveness of rivers to strays. Two hatcheries (Abernathy and Washougal) received virtually no strays whereas about 30% of the marked salmon in the Kalama and Lewis rivers were strays. It seems likely that some combination of flow, temperature and perhaps presence of conspecifics might influence the tendency of strays to enter a river. A greater understanding of the proximate factors influencing straying is needed before we can assess the possible genetic interactions among populations.

Events that affect water quality in the home river can influence straying (e.g., the eruption of Mt. St. Helens: Leider 1989). In addition to these dramatic situations, there is also some "background" year-to-year variation in straying (Quinn and Fresh 1984; Quinn et al. 1991). On a finer spatial scale, the tendency of hatchery produced salmon to enter their hatchery, as opposed to spawning in the river, can vary greatly from year to year (Table ..). Some of the factors that presumably affect general

attractiveness of rivers and hatcheries (flow, temperature, conspecifics, etc.) may also influence interannual patterns of straying.

Are there demographic patterns of straying?

It is not clear whether salmon stray

4. What factors may encourage straying? (normal hatchery culture, transplants (Bams, McIsaac and Quinn) outplants (Donaldson & Allen vs. Lister et al.), water changes...
5. Interaction between wind and hatchery-produced fish - Kalama steelhead strays into the hatchery and Elk River chinook fish that didn't enter the hatchery.

Discussion

Fundamental problem: to what extent are strays lost vs. actively comparing home to non-home sites?

Applied problems: how can straying be discouraged? what are the survival rates of strays vs. local? reproductive isolation, etc???

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Table 1. Straying (mean of yearly %s) by coho salmon reared and released in their river of origin or the Rosewall Creek experimental hatchery. All rivers are on the east coast of Vancouver Island, B.C. (Labelle 1990).

River of Origin	Release Site	Percent Straying Adults	Jacks
Trent River	Trent River	10.2	7.6
	Rosewall Creek	27.7	13.9
Black Creek	Black Creek	1.3	0.6
	Rosewall Creek	24.1	0.0
Little Qualicum River	Little Qualicum R.	0.5	0.7
	Rosewall Creek	8.3	2.3

Table 2. Mean annual percent of coho salmon straying from the Quinsam River, B.C. in relation to rearing history: spawned, reared and released from the hatchery ("hatchery"), spawned and initially reared in the hatchery but outplanted into the river ("colonization") and naturally produced ("wild"). Data from Labelle (1990).

	Rearing history		
Age group	hatchery	colonization	wild
Adults (age 3)	0.0	0.1	3.9
Jacks (age 2 males)	0.2	0.4	0.0

Table 3. Homing of Lewis River, Washington fall chinook salmon caught, tagged and released on site as fry ("wild"), caught, reared for about 10 weeks in a hatchery , tagged and released ("wild/hatchery"), and fry reared entirely in a hatchery ("hatchery"). Adult salmon were classified as having returned to the Lewis River, to adjacent rivers (one major tributary above and below the Lewis River), to other Columbia River locations or to locations outside the Columbia River system (McIsaac 1990).

	Distribution of Returning Adults (%)			
Rearing history	Lewis River	Adjacent rivers	Columbia R. system	Outside the Columbia R.
wild	96.8	<0.1	3.2	0.0
wild/hatchery	90.7	4.8	4.5	0.0
hatchery	89.7	5.7	4.6	<0.1

Table 4. Proportion of adult fall chinook salmon produced in the Elk River Hatchery, Oregon, returning to the hatchery as a percentage of the total return to the river (hatchery plus spawning grounds) (Nicholas and Downey 1983).

Return year	Percentage entering the hatchery
1972	45.2
1973	52.2
1974	15.5
1975	13.0
1976	5.9
1977	31.0
1978	10.8
1979	21.2
1980	10.8
Average	25.0

Table 5. The relationship betweeen straying of coho and chinook salmon and steelhead trout from the release site and the distance between rearing and release sites within the same river system (from Lister et al. 1981).

	Distance from rearing to release sites (km)		
	0	4-29	47-485
Number of studies	10	5	7
Mean % straying (range)	3% (0-13)	74% (37-100)	8% (1-39)
% straying to rearing site	-	77%	55%

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Abstract

This paper reviews studies on the patterns of straying of adult salmonids from their river or hatchery of origin, with an emphasis on Pacific salmon. The prevalence of straying varies greatly among populations. In general, introduced populations and salmon whose rearing history involves displacement or changes in water source may stray more than native stock and those reared and released on-site. Normal hatchery practices do not necessarily increase the tendency of salmon to stray, although evidence indicates that this may occur. While a generalized estimate of the proportion of salmon that stray would be useful, none seems appropriate because rivers and hatcheries vary so greatly in their tendency to produce and attract strays. There is evidence that the offspring of hatchery produced salmon may be less viable than those from local wild fish, hence straying between hatcheries and spawning grounds is cause for concern. Whether or not strays actually affect local gene pools depends not only on the prevalence of straying but on the degree of assortative mating and differential survival between populations. At present, fundamental gaps in our understanding of the genetic and environmental factors influencing straying hinder accurate prediction of the levels and consequences of straying.

Abstract

Overview of Salmon Enhancement Programs in Southeast Alaska

By Donald F. Amend

All five of the pacific salmon species are being enhanced by hatcheries in Southeast Alaska. Non-hatchery enhancement is not included in this report. Hatcheries are operated by the FRED Division, regional aquaculture associations (SSRAA, NSRAA), and private non-profit corporations (PNP's). Hatcheries played a minor role in the commercial harvest prior to 1985. Since 1985, the average annual harvest of enhanced chinook was 19,590 (10.2%), coho 195,650 (8.1%), chum 695,700 (31.2%), pink 475,000 (2.1%), and sockeye 58,480 (2.4%). At full production the percent of enhanced salmon in the commercial harvest is expected to be about 32.5% chinook, 18.2% sockeye, 16.2% coho, 5.8% pinks and 66.4% chum. The annual value to the commercial fleet has averaged $8.4 million annually and at full production is expected to average $36.8 million annually. The annual 3% enhancement tax paid by fishermen has averaged $2.39 million. Cost recovery is conducted only by regional aquaculture associations and PNP's. The annual revenue generated from cost recovery is estimated to be about $2.0 million.

DO CULTURE CONDITIONS OF HATCHERY-REARED SALMON AFFECT RETURN AND STRAYING OF ADULTS?

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ABSTRACT

Available data indicate that caution should be exercised in rearing certain species of salmon using accelerated growth regimens without additional research to explore if such regimens result in straying. We do know from our experience with accelerated rearing programs in Alaska for chinooks, for example, that the result is significantly lower returns of adults and that the returns are characterized by a high percentage of jacks. The reasons for this are unknown, but a better understanding of factors affecting smolt transformation and development in general are likely to lead to augmentation of current rearing strategies which will result in better developed smolts. Recent studies have revealed the importance of thyroid hormones on olfactory imprinting and development in general.

Studies comparing saltwater survival of yearling and zero-age coho salmon have showed differential rates of survival related to the timing of release into salt water and to the timing and extent of the plasma thyroid hormone surge. In one study, about 5 times as many yearling smolts survived as compared to zero-age smolts (Dickhoff *et al.*, 1982). Those data, taken together with the information that the thyroid hormone surge (T_4) during smolt transformation in the zero-age fish were half the amplitude of the yearlings, indicate that in addition to poor survival as postsmolts, some zero-age fish may not imprint properly on the stream where they are released. The reason for that is that thyroid hormones play an essential role in olfactory imprinting. Our studies on brain chemistry and brain circuitry changes during smolt transformation revealed sequential surges of select neurotransmitters before, during and after the plasma T_4 surge. Irregularities in any of these surges

may result in inadequate imprinting or lead to inadequate brain development, which in turn could affect subsequent behavior and survival.

There is to my knowledge no direct evidence for straying of zero-age fish, but research in this area should, in my view, be carried out before accelerated rearing programs are implemented.

Density dependent changes in chum salmon, Oncorhynchus keta, returning to Iwate prefecture, Japan

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In the last two decades, production of chum salmon in waters around Japan increased 5.8 million fish, 21.2 thousand tons (1970) to 50 million fish, 170 thousand tons (1990). Out of this production, Iwate contributes about 1/4 to 1/3 of the total.

The present study aims to clarify changes in some characteristics of the Iwate population during stock enhancement in the last two decades.

Stocks of three rivers in southern Iwate viz. Katagishi, Sakari and Kesen Rivers were investigated on their FL, BW, Age, and fecundity since 1975.

Body size in both FL and BW decreased gradually and the mode of change was almost identical with the three river stocks. Condition factor also decreased in the three stocks. Mean ages of adult increased gradually and the difference attained more than one year during the last two decades.

For the estimation of the growth during ocean resident years, scale radii and the number of circuli at each ocean resident year were analyzed. Age 4 fish, the dominant age class in recent years, were subsampled for scale analysis. Though annual variation in the length of scale radii and in the number of circuli were observed for each ocean resident year, stunted growth at first ocean year was prominent in recent years.

Highly significant negative correlations were detected between FL and number of fry released, FL and number of adult returned, and scale radii and number of fry released. A positive correlation was detected between mean age of return and the number of adult returned to Iwate prefecture.

Fecundity seemed to be decreased by increasing the size of egg in early 80s but became less obvious in late 80s.

More detailed information on their ocean resident stages is urgently needed.

Interactions between wild and cultured Atlantic salmon
A review of the experience in Norway

By Tor Heggberget, NINA, Norsk Institutt for Naturforskning, Trondheim, Norway

ABSTRACT

About 500 streams in Norway support Atlantic salmon. Most of the Norwegian salmon populations are characterized by small numbers of fish. Physical conditions, for instance water flow and temperature regimes, vary significantly along the Norwegian coast. Analyzes of age/size at maturity, timing of spawning and timing of smolt migrations clearly support the hypothesis of ecological adaptations to different physical environment. The differences in life history patterns are results of different selection pressures on salmon under varying physical conditions.

Proportions of cultured salmon have increased together with the rapid growth of the Norwegian salmon farming industry, and a maximum of 80 % cultured fish in spawning populations have been observed. The sources of cultured salmon in Norwegian streams are fish released for general enhancements of stocks, ocean ranching and escapees from the fish farming industry. Escapees from closed pen operations in the main source of cultured fish in nature.

Possible effects of the increasing numbers of cultured fish in Norway are discussed. The most striking effect so far, have been the introductions of parasites and diseases with cultured fish. In recent years, more than 30 populations of salmon have been completely wiped out by the monogean Gyrodactylus, and high mortality of adult salmon have been observed due to furunculosis in some streams. The long term effects of genetic interbreeding might result in extra mortality of wild fish due to erosion of local adaptations.

Suggestions to reduce negative effects of interactions from cultured fish are proposed.

Trends in Abundance of Hatchery and Wild Stocks of Pink Salmon in Cook Inlet, Prince William Sound, and Kodiak, Alaska[1]

D.M. Eggers, L.R. Peltz[2], B.G. Bue[3], and T.M. Willette[4]

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D.M. Eggers, L.R. Peltz[1], B.G. Bue[2], and T.M. Willette[3]. 1991. Trends in Abundance of Hatchery and Wild Stocks of Pink Salmon in Cook Inlet,and Prince William Sound, and Kodiak, Alaska. Can. Spec. Publ. Fish. Aquat. Sci.

Abstract

Trends in pink salmon (Oncorhynchus gorbuscha) abundance, production, and average weight of hatchery and wild stock catches, were examined for of Kodiak Island, Lower Cook Inlet, and Prince William Sound areas, 1960 to 1990. Wild pink salmon abundance was the sum of wild stock catches and escapements, which were aerial survey index counts expanded by estimates of stream life. Hatchery stock abundance was the sum of the estimated contribution of hatchery stocks to catches and the returns to the hatchery. Production estimates were based on hatchery stock returns from fry released at the hatchery and wild stock returns from parent escapement. Hatchery runs have increased greatly since the late 1970's and currently exceed wild stock runs. The total central Gulf of Alaska runs of pink salmon have increased and average weights have decreased since the early 1970's. Since the construction of hatcheries, wild pink salmon runs in Kodiak and Cook Inlet have not declined; however, in Prince William Sound a marked decrease in wild stock runs has coincided with the increase in hatchery

runs. Return per spawner for wild stocks and survival of releases for hatchery stocks were similarly affected by ocean temperatures. The recent decline in Prince William Sound wild pink salmon runs is believed to be the result of lower wild stock escapement levels due to the heavy exploitation of weak to moderate wild stock runs.

Introduction

Pink salmon (Oncorhynchus gorbuscha) have been produced in Alaskan hatcheries, since 1972. Hatchery production of pink salmon was initiated in 1972, with the Kitoi Bay hatchery in the Kodiak Area, (Figure 1). The facility was operated by the Fisheries Rehabilitation, Enhancement, and Development (FRED) Division, Alaska Department of Fish and Game (ADF&G) which was created by state legislation in 1971 following a period of very poor wild stock salmon runs throughout Alaska. Seven hatcheries are now producing pink salmon in the central Gulf of Alaska area (Table 1). These hatcheries are now operated by private nonprofit corporations.

These hatcheries are ocean ranching operations producing significant numbers

The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic

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Abstract:
The Baltic stocks of Atlantic salmon have beeen subjected to impact of human exploitation for many centuries. Especially during the last century, salmon populations have been subjected to dramatic changes in spawning stream access, fishing patterns, and fishing pressure.

At the end of the 19th century salmon spawned in 60-70 rivers in the Baltic proper. From 1940 onwards many of the large salmon rivers were dammed, most of them below the lowest spawning rapids for salmon. Methods for rearing salmon up to the smolt stage were developed and the first smolt releases started around 1950. The number of smolts released in Swedish rivers has gradually increased to between 2-2.5 milj released in the middle of the 1980s. During the last ten years other countries have started salmon release programs resulting in an annual release of about 3 milj. smolts. The smolt releases have been successful showing high survival rates of stocked fish. Today, only about 20 rivers, most of them in Sweden, are attainable for natural spawning runs. The runs are very weak.

Before the second world war the Baltic salmon fishery mainly consisted of coastal and river catches of spawning migrators ascending the rivers. After the war the an off-shore drift gillnet fishery has been developed, nowadays making up the major part of the total catch. As a consequence, the spawning runs of wild salmon have decreased dramatically. One houndred years ago the natural production of salmon smolts from the Baltic salmon rivers was around 7-8 milj. smolts annually. In the beginning of 1970s the wild smolt run to the Baltic was about 2 milj. At present, only about 0.5 milj. wild smolts are produced to the whole Baltic proper, which is only about 20% of still remaining smolt production capacity of the rivers.

The off-shore fishery on mixed populations in the central areas of Baltic proper leads to an extremely high fishing pressure on the Baltic salmon stocks. Wild stocks are unable to cope with the present exploitation rate. As a result, the number of wild spawners in natural streams gradually dimnishes. In absence of a compensatory programme, a reduction in stock-size of the magnitude showed by wild salmon in the Baltic would decrease catch per unit effort to such a degree that a salmon fishery would be meaningless. At present, however, about 90% of the salmon smolts leaving Baltic rivers are of hatchery origin. Depending on extremely high egg-to-smolt survival rates the reared stocks can withstand this high exploitation. It is concluded that the success of hatchery enhancement programs in combination with lack of effective regulations allowing a high catch per unit effort in the off-shore fishery, explains a major part of the sad fate of remaining wild salmon stocks in the Baltic.

A biologically sound management programme for the Baltic salmon is bound to include a stop (or strict regulation) of the off-shore fishery on mixed stocks. Salmon stocks should be exploited in relation to the carrying capacity of individual populations, by a more terminal fishery at the coast, or in rivers.

However, an established off-shore fishery in the main Baltic, including (at least) 7 nations, has so far made any kind of regulations difficult. A recent, and hopefully more accessible management program is a compromise, suggesting a ban on salmon fishing outside 24 nautical miles from the coast. The fishery closer to the coast will be supported by net-pen delayed releases of salmon at selected areas along the coast of the Baltic main basin. The proposed off-shore fishery regulation would increase escapement considerably, while total catch (in tons) would remain unchanged. If the proposal is accepted, we estimate that most wild salmon stocks would have a possibility to recover within 3-4 generations. If not, we believe that the fate of all the wild salmon stocks in the Baltic are at stake within a few additional salmon generations.

Genetic Variation in Timing of Anadromous Migration Within a Spawning Season in a Population of Pink Salmon.

IN PRESS / REVIEW

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Smoker, W.W., A.J. Gharrett, and M.S. Stekoll. 1991. Genetic variation in timing of anadromous migration within a spawning season in a population of pink salmon. Can. J. Fish. Aquat. Sci. Spec.Publ. 00:000-000.

Abstract

Variation of the timing of anadromous migration and spawning during the spawning season, and consequently of seaward migration of offspring fry, affects variation of survival and fitness in pink salmon (Oncorhynchus gorbuscha). We analysed variation of anadromous timing in 120 families made by hierarchical mating of 60 males and 120 females representing both early-run and late-run subpopulations in Auke Creek, Alaska. The families were incubated separately, released as fry with identifying coded microwire tags, and recovered in the stream as adults. There were significant sire effects indicated by significant differences of return date between families spawned on the same day by different fathers ($P < 0.045$ male offspring, $P < 0.040$ female offspring). This is evidence of additive genetic variation underlying the variation of timing. Significant differences between returning dates of offspring of early-run parents and of offspring of late-run parents, spawned 34 days apart, ($P<0.0001$ males or females) are also consistent with such genetic variation. Heritability of timing of anadromous migration in odd-year pink salmon spawned in Auke Creek, Alaska, is about 0.2 (SE 0.16) in males and in females about 0.4 (SE 0.20); both estimates are based on effects of sires mated on the same day. Genetic variation of return timing is probably adaptively important to the fitness of pink salmon in Auke Creek.

GENETIC STOCK IDENTIFICATION STUDY OF YUKON RIVER CHUM AND CHINOOK SALMON

by

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ABSTRACT

The United States and Canada opened negotiations in 1985 concerning the allocation of Yukon River chum (*Oncorhynchus nerka*) and chinook salmon (*O. tshawytscha*). Approximately 90% of the in-river harvest is by U.S. fishermen. An unknown proportion of this catch would have returned to the Canadian portion of the Yukon Drainage. In order to negotiate an equitable treaty between the two countries, it is necessary to determine what proportion of the U.S. harvest is of Canadian origin. In 1987, the U.S. Fish and Service began a genetic stock identification (GSI) study in the Yukon River to address this problem.

Tissue samples were taken from 34 chum salmon populations and 30 chinook salmon populations and genetically characterized using enzyme electrophoresis. Nineteen variable characters were used to analyze the population structure of Yukon River chum salmon, and 22 variable characters in chinook salmon. Genetic separation between the summer run and fall run of chum salmon was very good as determined using simulations of stock mixtures of given contributions of each stock. Separation between U.S. fall run stocks and Canadian fall run stocks was also good. Estimates down to the stock level are not reliable for management purposes at this time. Resolution of an additional known 14 variable characters, and the used of mtDNA variation, may allow reliable estimates to the stock level. Genetic separation between U.S. and Canadian chinook stocks was very high as determined by simulations. Separation was also very good for sub-groups within both the U.S. and Canadian groups. Accuracy down to the stock level is substantially better for chinook salmon than for chum salmon, but is still not reliable for management purposes. Resolution of an additional 13 variable characters, and use of mtDNA variation, may allow discrimination to the stock level.

Samples have been taken from the mixed-stock fishery at the mouth of the Yukon River and estimates of stock contribution were calculated for the years 1987-90. Due to legal problems concerning management of the Yukon River fishery, these results will not be released until a thorough peer review of the data.

Fred W. Allendorf, Division of Biological Sciences, University of Montana, Missoula, MT 59812. U. S. A. CONSERVATION OF SALMONID FISHES: WHY, WHAT, AND HOW.

There are three questions that must be addressed before we can develop objectives and methods for conserving salmonid fishes: (1) Why should we preserve salmonid fishes? (2) What should we attempt to preserve? and (3) How should we conserve salmonid fishes? It is important to address the issue of why we want to conserve salmonids in order to unify our efforts and to obtain the resources that are necessary to do it. The question of what we should be preserving is an important and perhaps surprisingly difficult one. Loss of local salmonid populations is occurring throughout the world. We cannot halt this ongoing process; that is, we cannot conserve all local salmonid populations. Therefore, choices and compromises must be made. How do we best use our limited resources to conserve genetic diversity in salmonid fishes? Our first priority should be to protect extant wild populations and their habitat. The loss of genetic diversity is usually irreversible. Therefore, our primary efforts should be to prevent such losses.

A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska for Juvenile Pacific Salmon

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Abstract

The present feeding demand on zooplankton resources by wild and ocean ranched juvenile Pacific salmon in Prince William Sound is estimated between 1.0 and 4.0 percent of the total "herbivore" production, and 4.0 to 16.0 percent of the annual macrozooplankton production in the region. When annual fry losses to early ocean mortality are taken into account, the feeding demand associated with growth rates averaging 3 to 4 percent of the body weight per day fall to 0.4 to 1.6 percent of the total herbivore production and 1.5 to 5.0 percent of the macrozooplankton production. Uncertainties associated with the numerous assumptions used in this analysis are discussed in relation to what is understood about the biology and ecology of salmon in Prince William Sound and elsewhere.

Introduction

Successes with ocean ranching of Pacific salmon in Prince William Sound, Alaska are beginning to raise management and enhancement questions about the ability of the region to support even larger releases of juveniles planned for coming years. Hatchery released salmon now comprise 50 percent or more of all adults returning to common property fisheries in the Sound. In view of a growing controversy over apparent adverse interactions between hatchery and wild salmon stocks in Washington, Oregon and British Columbia, it seems appropriate to examine the question of carrying capacity as one means to assist with the continued enhancement and management of these vital commercial and subsistence resources in the Sound. The assessment presented here follows accepted ecological theory but is based on several untested assumptions. As a result, conclusions derived from the formulation are probably valid only as general guidelines and perhaps most useful as assertions to be formally examined under field and experimental conditions.

Parsons (1987) presents generalized carbon budgets for open ocean, shelf, fjord and estuarine ecological zones in the North Pacific. Because of its depth and oceanographic characteristics, Prince William Sound is best described as a complex fjord-type ecosystem (Schmidt, 1977). In the deep fjord environment a large percentage of the organic matter produced by phytoplankton is

INFO TO SAVE FOR USE IN CHAPTER ON BIOLOGICAL ISSUES:

Successful hatchery development may actually cause further depletion of already suffering natural stocks, some to the point of extinction. This ironic effect is due to several factors:

1. The extent of habitat and other environmental damage can be camouflaged by hatchery production so it may go unrecognized and unchecked, impeding survival of natural runs.
2. A large influx of hatchery fish may compete with natural stocks for food and other survival necessities. There has been considerable debate about the question of "ocean carrying capacity." While it is not too difficult to determine how many fish can survive or spawn in a stream or hatchery tank, data is not yet available to show just how many salmon can be adequately sustained in the ocean environment. For example, when the average body weight of pink salmon throughout Alaska was significantly lower in 1991 than normal, there was speculation that massive hatchery production of pink salmon may have pushed populations beyond what the ocean can adequately sustain. If indeed there is such a threshold, over-production of hatchery fish could potentially harm natural stocks.
3. Fisheries management decisions and allowed harvest levels are based on total amounts of fish available. If only a small percentage of total fish population in an area is natural fish, the percentage mandated to be left for escapement may be high enough to sustain hatchery stocks but insufficent to sustain the declining natural runs.

Ironically, the success of hatcheries, and the associated decline of natural runs, may eventually even spell trouble for the future of **hatchery** stocks. This is because the genetic diversity found in natural runs, and introduced into hatchery stocks through broodstock from wild fish stocks, is important to the long-term health and adaptability of all stocks including hatchery fish. After a number of generations, hatchery fish can lose their genetic diversity and thus lose their ability to adapt to changes and survive.

The commissioner may place conditions on a PNP permit, ~~this~~ includes a provision that donor stock eggs must be from the department or a source approved by the department. This action is supported by Board of Fisheries regulations 5 AAC 41.001-41.100 for the fish transport permit process. 5AAC 41.005 states that no person may transport, possess, export from the state, or release into the waters of the state, any live fish unless the person holds a fish transport permit issued by the commissioner and the person is in compliance with all conditions of the permit and the provisions of the chapter. 5 AAC 41.030 states that the commissioner will only issue a fish transport permit if it is the department's determination that the proposed transport, possession or release of fish will not adversely affect the continued health and perpetuation of native, wild, or hatchery stocks of fish. All fish transport permit applications are reviewed and signed (recommending either approval or denial) by the ADF&G Principal Pathologist and the ADF&G Principal Geneticist, as well as the regional supervisors for the fisheries divisions, the Chief of Technology and Development, the FRED division director, and the commissioner. The potential for disease and genetic impacts are primary considerations in this review process.

put in genetics section.

Additional permit conditions include: restrictions on ~~no~~ placement of salmon eggs or resulting fry into the waters of the state; ~~except as designated in the permit~~; restrictions on sale of eggs or resulting fry; ~~no~~ release of salmon; ~~before departmental approval;~~ destruction of diseased salmon; departmental control over where salmon are harvested by

conditions of the turnaround

The commissioner of ADF&G may issue a nontransferable permit to a nonprofit corporation for the construction and operation of a salmon hatchery after the permit application has been reviewed by the regional planning team. ~~A hatchery permit is nontransferable~~. A public hearing, held in a central location in the vicinity of the proposed hatchery facility, is required at least 30 days before ~~the issuance of~~ a permit is issued.

~~The commissioner may place~~ Conditions may be placed on a PNP permit, including a provision that donor stock eggs must be from the department or a source approved by the department. ~~Additional~~ Other permit conditions include restrictions on placement of salmon eggs or resulting fry into the waters of the state; restrictions on sale of eggs or resulting fry; the timing and conditions of releasing salmon; destruction of diseased salmon; departmental control over where salmon are harvested by hatchery operators; and ~~the~~ siting requirements so that reasonable segregation from natural stocks occurs ~~but~~ while still allowing when feasible, allows returning hatchery fish to pass through traditional salmon fisheries.

The commissioner may alter, suspend, or revoke a PNP permit if the operator fails to comply with the terms and conditions of the permit within a reasonable period after notification of noncompliance. The commissioner may also alter the permit or ~~initiate a~~ terminate ~~of~~ the operation, if it is found that the hatchery is not in the best interest of the public.

Fish released by hatchery operators are available to the people for common use in the same way as natural stocks until they return to the location established by the department for hatchery harvest. The Board of Fisheries may, after a permit has been issued, amend by regulation the terms of the permit relating to the source and number of eggs, the harvest by hatchery operators, and the ~~locations designated by the department for harvest by the operator (i.e.~~ locations of hatchery special harvest areas) (AS 16.10.440B). However, this authority has never been used.

~~The department is required by statute to provide assistance before and after a permit is issued within the limits of time and resources available to staff. AS 16.10.445 reinforces that the department shall approve the source and number of salmon eggs for hatchery operators. Salmon eggs shall first be taken from stocks native to the area in which the~~ biological

hatchery is located. The sale of salmon and salmon eggs by operators is addressed in AS 16.10.450. After the operator uses funds from such sales for debt service and reasonable operating costs, any remaining funds shall be expended on other fisheries activities of the qualified regional association. Also, fish returning to hatcheries and sold for human consumption must be of comparable quality to fish harvested by commercial fisheries in the area, and must be sold at prices commensurate with the current market.

An annual report must be filed with the department by December 15 of each year that contains information on hatchery returns, numbers of eggs taken, and numbers of fry or smolt released.

The permit application procedures for a PNP hatchery, the regional comprehensive salmon planning process, and general provisions on the permitting and operation of PNP hatcheries are described in regulations 5 AAC 40.100-40.990. Permit application procedures include: pre-application assistance, a management feasibility analysis, the permit application and fees, determination of acceptance by the department for formal review, regional planning team review, a provision for requesting additional information, completeness determination by the department, the public hearing process, review and determination by the commissioner (this includes six major criteria), and a provision for reconsideration. The departmental review of all PNP hatchery permit applications includes review and comment by all fisheries divisions, the Habitat Division, the Principal Geneticist, and the Principal Pathologist. A public hearing and full review by state and Federal agencies through the coastal zone review process is also required.

A Basic Management Plan (BMP) is developed as part of the actual permit. The BMP includes a complete description of the facility including the special harvest area, brood stock development schedules, and descriptions of brood stock and hatchery stock management. Where deemed necessary by the management divisions, marking programs for hatchery-produced fish are required in the hatchery permit and BMP. Such programs are usually optional, unless the fisheries management divisions specify the need for special in-season management capability during the permit or permit alteration process. Representative numbers of most species are routinely coded-wire tagged at most facilities and other (e.g. otolith) mass marking techniques are being developed. When a permit becomes operational, an Annual Management Plan (AMP) is

VI. BIOLOGICAL/GENETIC ISSUES

In November, 1991, in Cordova, Alaska, the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, convened a group of world-renowned experts to examine "The Biological Basis for Maintaining Strong Co-existing Stocks of Natural and Enhanced Salmon Populations in Alaska." This workshop followed a series of international symposiums on this topic during the past two years in Norway, Canada, Idaho, Washington, and Japan. Top fisheries biologists, ecologists and geneticists from the United States, Norway, Sweden, the Soviet Union and Japan were present at this workshop. As a follow-up to the workshop, the group intends to produce a summary report and list of recommended policies and procedures to be considered by the state of Alaska in managing its wild and enhanced salmon stocks.

The cumulative effect of hydroelectric dams, habitat destruction, over-fishing and large-scale hatcheries has lead to the decimation of many wild salmon stocks in Pacific Northwest states. Biologists in states with a long history of hatchery programs are generally less enthusiastic about these programs than biologists in areas such as Alaska and British Columbia with comparatively more recent programs. Although poor hatchery practices can clearly endanger wild salmon populations, scientists do not agree on the extent to which hatcheries with sound practices can co-exist with sustained healthy runs of wild salmon.

The lack of consensus among scientists results from insufficient data and research. Even where information exists, however, it is often subject to conflicting interpretations. To complicate matters, results of specific studies may not be transferable to other areas or salmon species, and year-to-year environmental changes may affect the results of studies.

The Genetic Effects of Hatcheries

Most scientists agree that it is essential to have healthy wild stocks in order to maintain the health and genetic diversity of both wild and hatchery stocks; genetic diversity must be preserved. Scientific knowledge about the genetic impact

on wild stocks of hatchery fish, however, is still incomplete. Reduction in the fitness of salmon stocks, to the extent it has been documented, may involve numerous factors. Most scientists agree that hatcheries can complicate mixed-stock fisheries and affect the genetic composition of wild fish stocks. Scientists do not agree on the degree to which genetic changes affect the short- or long-run fitness of wild stocks.

Straying and intermingling of stocks is a major concern to scientists. The extent of straying, the mechanism causing imprinting, and the success of crossbreeding are largely unknown. Large-scale ocean ranching appears to set the stage for straying of wild stocks in the harvest areas of enhanced stocks and also for hatchery fish to stray into the natural streams. What impact this has on the genetic diversity of salmon stocks in a given region is a question that remains to be answered.

It is known that the greater the distance between the donor stream or hatchery and the release site, the greater the amount of straying. **Many scientists are concerned about the extensive releases at remote sites practiced by many hatchery operations today,** with many more planned for the future. They fear that such straying could potentially, in time, destroy genetic diversity -- resulting in a permanent, irreversible loss. Some scientists believe remote releases should be banned altogether. Others believe they should be permitted with stringent controls and careful monitoring.

Ocean Carrying Capacity

Some scientists suspect that the carrying capacity of freshwater rearing areas, nearshore waters, and the high seas for salmon may be exceeded by large-scale releases of hatchery salmon. A reduction in the average size of salmon has been reported throughout the Pacific region in 1991, but various factors may be responsible. Some researchers believe ocean conditions affect the size of salmon more than competition. Much evidence, however, supports the theory of density-dependent growth for some salmon species, although there is considerable debate regarding its occurrence.

Disease

Few studies document the transmittal of diseases between hatchery and wild salmon and there is no documentation of such transmittal in Alaska. Where transmittal of a disease by hatchery salmon has been documented, it occurred after fish were transplanted long distances. Hatchery fish appear to be more vulnerable to disease than wild fish because of the stress of hatchery conditions and large concentrations of eggs and fry.

State Genetics Policy

Describe here the current state policy and the process of reviewing Fish Transport Permits.

CHAPTER VIII. BIOLOGICAL/GENETIC ISSUES

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Since 95% of the growth of salmon occurs in the sea

Disease

looks very promising), the use of coded-wire tags is not going to be replaced in the foreseeable future. The CWT Lab is a vital link in the in-season management of fisheries in Southeast and Prince William Sound. Chinook salmon fisheries from California to Alaska are managed by treaty convention on the basis of coded-wire tag data. The massive returns of hatchery pink salmon to Prince William Sound is critically assessed in season tag data. Coastwide, this laboratory has the reputation of being the premier operation of its kind.

Fish Pathology Laboratory:

Active laboratories will be maintained in both Juneau and Anchorage to provide continuing fish health services to salmon hatcheries, mariculture operations, other fisheries divisions, and the public-at-large. The basic function of the fish pathology discipline is to implement policies and procedures that guard against the spread of fish and shellfish diseases in Alaska. The two laboratories serve this function. Routine diagnostics and processing of transport permits for finfish and shellfish will continue as in the past. Monitoring for viral hemorrhagic septicemia virus in Pacific cod will continue. Mapping the distribution and infection rates of bitter crab disease in tanner crabs will go forward in association with the ADF&G Commercial Fisheries Division and the crab fleet. Oyster spat certification for import into Alaska will remain a significant task for the pathologists. Transport permits for aquatic farming activities will increase significantly.

Genetics Laboratory:

The primary service of the genetics discipline is to implement policies and procedures that protect and maintain the genetic uniqueness of Alaska's wild salmon stocks in the face of North America's largest salmon enhancement program. In the coming year, the department's fish genetics policy will be reexamined and updated. Routine processing of transport permits for finfish and shellfish will continue as in the past; however, contentiousness now accompanies a growing number of transport requests, and it is our intent to establish a genetic-screening program for salmon stocks so that answers to tough questions regarding the genetic implications of stock movement can be facilitated. The Genetics Laboratory is now equipped and ready to process samples that will reveal the genetic conformation of our wild salmon stocks. This compatibility has application for stock separation in mixed-stock interception fisheries, identification to the country of origin of salmon caught on the high seas, and examination of the

interaction of hatchery stocks and wild stocks. The incumbent principal geneticist is an expert on techniques employed to sterilize fish and shellfish——a concept that has great practical application in Alaska. FRED Division will work toward using sterile animals for outstocking in projects where fertile animals would have a genetic impact on indigenous wild stocks and thus prohibit such projects. The development of sterile Japanese scallop spat is an example; stocking of sterile rainbow trout for sport fishing is another example.

Limnology Laboratory:

The Limnology Laboratory and the lake-enrichment and water-quality capabilities associated with it are in great demand by cooperators across the state. This unit generally has 30-40 cooperative projects ongoing around the state during any given year. Nutrient enrichment of sockeye salmon lakes has proven to be an extremely cost-effective tool for rehabilitating depressed sockeye salmon runs, and such projects will continue into the future. Karluk Lake is an outstanding example of what can be done; in 1990, it had the largest return of sockeye salmon since good record-keeping was established in the early 1900s. This return was made up principally of late-run adults that, as juveniles in 1986, received the benefits of our initial application of fertilizer to Karluk Lake. Similar projects will continue in Southeast, Southcentral, and Prince William Sound, and new ones will be established on the Alaska Peninsula. Work will continue on marrying habitat features of lakes to forecasting adult fish returns in subsequent years. FRED scientists have used this approach to sockeye salmon forecasting, and in subsequent years will extend it to the marine environment. Water-quality studies on [illegible] will go forward with funding from the Department of Natural Resources. The United States Environmental Protection Agency is interested in establishing a laboratory to conduct water-quality studies on lakes in populated areas of Alaska. The North Slope Borough has requested limnologists to participate in borough enhancement and water-quality planning in the coming months.

Library Services:

Fishery scientists, planners, and managers in two of the department's fishery divisions (Sport Fish & FRED) are served by a centralized library managed by the FRED Division. Funding for the library is shared among them and is prorated on a user basis.

operators is addressed in AS 16.10.450. After the operator uses funds from such sales for debt service and reasonable operating costs, any remaining funds shall be expended on other fisheries activities of the qualified regional association. Also, fish returning to hatcheries and sold for human consumption must be of comparable quality to fish harvested by commercial fisheries in the area, and must be sold at prices commensurate with the current market.

The department may inspect the hatchery facility at any time the facility is operating. Each facility is inspected at least every other year, and each brood stock is examined for disease prior to its use in a hatchery.

An annual report must be filed with the department by December 15 of each year that contains information on hatchery returns, numbers of eggs taken and numbers of fry or smolt released.

The permit application procedures for a PNP hatchery, the regional comprehensive salmon planning process, and general provisions on the permitting and operation of PNP hatcheries are described in regulations 5 AAC 40.100-40.990. Permit application procedures include: pre-application assistance, a management feasibility analysis, the permit application and fees, determination of acceptance by the department for formal review, regional planning team review, a provision for requesting additional information, completeness determination by the department, the public hearing process, review and determination by the commissioner (this

Few studies document the transmittal of diseases between hatchery and wild salmon and there is no documentation of such transmittal in Alaska. Where transmittal of a disease by hatchery salmon has been documented, it occurred after fish were transplanted long distances. Hatchery fish appear to be more vulnerable to disease than wild fish because of the stress of hatchery conditions and large concentrations of eggs and fry. Norway has had considerable problems with disease transmitted by farmed salmon that have escaped and mixed with wild stocks.

State Genetics Policy

Describe here the current state policy & Genetics Lab, *and the process of reviewing Fish Transport Permits.*

Salmon eggs must first be taken from stocks native to the area in which the hatchery is located.

Active fish pathology labs are maintained in both Juno & Anch.

Broodstock mgmt.