From:	N.J. Hillstrand
To:	House Fisheries; House Resources; Senate Resources
Subject:	Please oppose HB 295, HB 169, SB 210
Date:	Tuesday, February 20, 2024 11:33:02 AM
Attachments:	1992 LEGISLATIVE REVIEW HATCHERY EXECUTIVE SUMMARY .pdf Sustainable fish policy.pdf Hatchery salmon have genetic differences from wild populations in only a few generations .pdf AKhatcheries.pdf

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Greetings
I worked for the ADFG, enhancement and rehabilitation division, FRED , as a fish culturist and habitat rehabilitator over a 21 year period and am now a seafood processor, market retailer and internet sales for the past 32 years at welovefish.com. Our Alaskan Corporation Pioneer Alaskan Fisheries has been in business since 1965.

While well-meaning bills such as HB 295 HB 169 and SB 210 attempt to force help, these do not provide adequate oversight, or monitoring for Alaska's collapsing salmon fisheries. Unfortunately these bills unwittingly promote grave potential to adversely affect and jeopardize the future of wild fisheries in Alaska. Sometimes the cure can be worse than the disease.

To make sound policy decisions regarding Alaska's important salmon resources, the many adverse hatchery/ wild interactions deserve a much more comprehensive approach rather than piecemeal fragmented hatchery or enhancement bills based on narrow council and opinion.

A comprehensive approach would first consider best available information, with continual update, not based on whim or opinion but on comprehensive reviews.

First, please consider the (attached) Executive Summary of the **Legislative Review on Salmon Enhancement** by the Senate Special Committee on Domestic and International Fisheries in 1992. This took almost two years to prepare to impart what was known through 1992. This comprehensive document needs to be updated to bring the best available information to the legislature to ensure sound policy decisions are not based on whim.

Second, consult the (attached) State Policy for Sustainable fisheries 5AAC 39.222. This Alaska policy took four years to create and warns with clear caution of enhancement interaction.

Third, Evaluation of the (attached) hatchery interaction by the Environment and Natural Resources Institutes University of Alaska Anchorage.

Fourth, observe results of the current Alaska Salmon Research Task Force with its final report due out June 27, 2024.
https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-salmon-research-task-force

Fifth, keep up to date on the most recent science, for instance February 14, 2014 NOAA posted

https://www.fisheries.noaa.gov/feature-story/cracking-code-scientists-use-dna-examine-differences-between-hatchery-and-wild-chinook
(attached is the actual paper) last week's collaborative research provides some of the strongest and most fine-scale evidence to date suggests that hatchery rearing can inadvertently select for traits that may be disadvantageous in the wild. This could have downstream implications for native stocks conducted by scientists from the Alaska Fisheries Science Center, Alaska Department of Fish and Game, and Texas Christian University. This new genetic study shows hatchery salmon's adaptation to their environment can lead to potentially adaptive genetic differences between hatchery and wild salmon populations in only a few generations.

There is a weight of knowledge showing caution. To have what the above Senate Committee called legislative "working documents", can provide a focus for the Legislature and others to work together to make sound policy decisions.

Without comprehensive "working documents" of the best available information as 5 AAC 39.222 asserts, we place further stress on our fisheries and add stress not cure problems.

Thank you for considering comprehensive knowledge and a more broad council for sound policy. Please advise if I may help in any way.
Kind Regards and respect
Nancy Hillstrand
Coal Point Trading Company
Pioneer Alaskan Fisheries Inc
4306 Homer Spit
Homer, Alaska 99603
907-399-7777

Senate Resources 02.21.24 note:
Hillstrand Attachment #1

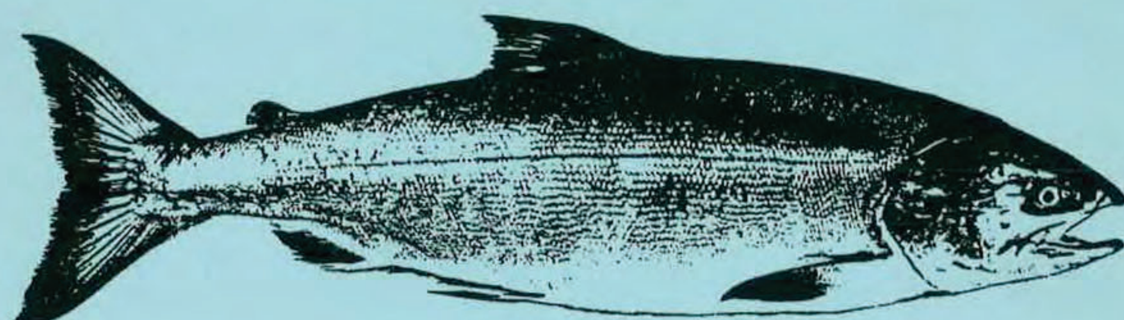
LEGISLATIVE REVIEW

OF THE

ALASKA SALMON

ENHANCEMENT PROGRAM

EXECUTIVE SUMMARY



Alaska State Senate
Special Committee on
Domestic & International Commercial Fisheries

FINAL REPORT

DECEMBER 1992

Alaska State Legislature

SENATE

Official Business

P.O. Box V
State Capitol
Juneau, Alaska 99811

December 1992

The Senate Special Committee on Domestic and International Commercial Fisheries has been conducting a review of the Alaska salmon enhancement program since May of 1991. The work of this particular committee concludes with the publication of both this final report and an additional chapter in draft form which contains an economic analysis of the enhancement program. It is the Committee's hope that these two reports will be used during the next few years as "working documents," providing a focus as the Legislature and all those interested in Alaska's fisheries enhancement efforts work together to make sound policy decisions regarding this important state program.

A number of people and agencies have worked hard on this review project. The Committee would especially like to thank legislative staff members Molly McCammon, Mary McDowell, Ginny Fay, Jo-Eve Benedict and Doug Rickey, the Alaska Department of Fish and Game, the Commercial Fisheries Entry Commission, the Legislative Research Agency, and the faculty members of the University of Alaska who have contributed to the project.

Many individuals and organizations from throughout the state have also put considerable amounts of time, thought and effort into following the progress of this review, testifying before the Committee, submitting written comments, and providing information for use in the economic analysis. I want to thank everyone for your willingness to be involved and work constructively towards the goal of improving the state's enhancement program.

Senator Dick Eliason, Chairman

Senate Special Committee on
Domestic and International
Commercial Fisheries

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Chapter I

INTRODUCTION

In May 1991, the Alaska Senate's Special Committee on Domestic and International Commercial Fisheries initiated a review of fisheries enhancement in Alaska. While the Committee recognized the success of the salmon enhancement program, its statutes, regulations, and role in Alaska's fisheries had not been thoroughly reviewed since the program's inception nearly 20 years ago.

During the last 20 years, Alaska's Salmon Enhancement Program and fishing industry have undergone enormous changes. New variables are influencing Alaska's fisheries which had not been anticipated when the enhancement laws were enacted: the implementation of limited entry, the advent of fish farming, oil spills, a worldwide glut of salmon markets, the rising and crashing of various fish and shellfish stocks, enactment of the federal Endangered Species Act, impacts of trawling and highseas driftnets, annual state revenues that grew dramatically for some years and are now declining, and the possibility of enhancement and pen-rearing of fish and shellfish species not thought to be feasible in the past.

The Committee did not initiate its review of the enhancement program with any preconceived notion of conclusions, recommendations, or actions. Rather, it began with the recognition of the Legislature's responsibility to review the history and evolution of the program and establish future policy direction. ***The goal was to assemble and analyze information about the program and the global context in which it operates. The review was to serve as the first step in ensuring that current and future enhancement efforts will be economically and biologically sound, while fulfilling the goals for which the program was established.***

Legislative staff members were assigned to conduct most of the research, with the assistance of the Legislative Research Agency and private contractors. Staff were directed to compile a report listing possible options for consideration, rather than specific recommendations, after each chapter. The aim was to create a "working document" which would provide policy-makers with information and a full range of approaches to consider. The University of Alaska, Fairbanks was placed under contract to provide an economic benefit-cost analysis.

In February 1992 the Committee released the draft of its report entitled, "Legislative Review of the Alaska Salmon Enhancement Program." Copies of the draft report and its executive summary were distributed statewide. Since the University's economic study was just getting underway at that time, the economics chapter included only an outline of the economic research to be conducted.

On February 24, 1992, the Committee held a statewide teleconference to hear public comment on the draft report. The hearing was well attended and resulted in several hours of testimony and discussion. Many individuals and groups also submitted written comments to the Committee. ***Most public comments spoke to agreement or disagreement with the options presented. A few also suggested minor changes or corrections in the report content.*** The public comments have been made available to the Legislature, and are included in the appendices to the final report, which are available from the legislative library in Juneau.

The issue raised most frequently in public comments was the status of wild fish stocks and enhanced stocks, especially in the context of fisheries

management and allocation. That very issue, raised by the Alaska Board of Fisheries, was one of the primary reasons that the Committee undertook the review of the enhancement program. There appeared to be near-unanimous consent among fishermen, hatchery operators, fisheries managers, members of the general public, and legislators that a successful enhancement program necessitates that the sustained yield of Alaska's wild stocks be specified, in law, as the highest management priority.

After considering public comment, the Committee decided to take immediate action on a "wild-stock priority" bill. Senate Bill 457, sponsored by the Committee, passed the Legislature in May 1992 and became the first legislative action to result from this review of the enhancement program. (A copy of SB 457 is included in Chapter V of the final report.)

The University of Alaska's work on the economic studies took more time than originally anticipated. The benefit-cost analysis was not completed until the end of December. Because the Committee is a temporary, special committee established only for the duration of the 17th Legislature, it was not possible for the Committee to hold public hearings on the economic portion of the review project. ***Since the economics chapter has not yet undergone scientific peer review or the same public review that the rest of the chapters have received, the Committee decided to publish it separately in "draft" and make it available to the public at the same time as this final report containing the remaining chapters.***

This final report is largely the same as the draft report that was distributed in February 1992. Minor revisions have been made to update information and to incorporate several suggestions made in public comments.

Both the final report and the draft chapter on economics are being submitted to the incoming 18th Alaska Legislature. A letter accompanying the two documents requests that public hearings be held on the draft chapter, that consideration be given to the information and suggested options in the full report, and that legislative committees carry on with the work begun in this review.

Chapter II

HISTORY AND DEVELOPMENT OF SALMON ENHANCEMENT IN ALASKA

The development of Alaska's hatchery program was an evolutionary process. Beginning as early as the late 1800s, attempts at hatchery production of salmon were undertaken by the federal government and private industry. As harvests of salmon declined, interest in efforts to mitigate the economic impacts through enhancement and hatchery production increased. However, enhancement efforts were minimal until a dramatic drop in salmon harvests in the 1960s and 1970s prompted state action.

The expressed goal of the state hatchery program was to produce additional fish to supplement the existing wild salmon stocks. The Legislature acknowledged concern about the potential for detrimental biological impacts of large-scale hatchery development on wild stocks, particularly from the interaction between wild and hatchery fish. However, program development was primarily driven by concern about the economic decline of the fishing industry.

In 1969 the state began receiving large sums of revenue from oil and gas leases on the North Slope. The Legislature decided to channel some of the future public income from such nonrenewable resources into development of renewable resources for long-term economic stability. The salmon resource was an obvious candidate for this type of investment.

Throughout the 1970s, laws were enacted to facilitate development of a major fisheries enhancement program in Alaska. Program components included:

- creation of the Division of Fisheries Rehabilitation, Enhancement and Development (FRED) within the Alaska Department of Fish and Game,

- passage of a number of bond issues authorizing tens of millions of dollars for capital improvements for state hatchery facilities,

- authorization of private nonprofit (PNP) corporation hatcheries, and

- creation of regional aquaculture associations (as PNP) responsible for the regional planning and coordination of salmon enhancement activities.

After the initial start, it became increasingly apparent that a successful hatchery program was going to be more expensive than originally anticipated. New methods of financing were sought. The Legislature made funds available to PNP hatcheries through the Renewable Resources Development Fund, and by expanding the commercial fisheries loan program to include hatcheries. A separate fisheries enhancement loan program was later established. Statutes were also amended to allow proceeds from PNP sales of salmon or eggs to be applied to debt retirement, as well as operating costs.

A salmon enhancement tax was enacted that allows commercial fishermen in a region to vote to pay an assessment of 1 to 3 percent of the ex-vessel value of the landed salmon catch. The proceeds of this assessment are appropriated by the state to regional aquaculture associations. State law also provided for the establishment of other PNP operations run by private nonprofit corporations which are independent of regional associations, sometimes called "Mom and Pop" hatcheries. Both regional associations and "mom and pop" hatcheries are "PNPs" under state law. In this report, any reference to PNPs refers to both types unless otherwise indicated.

Legislation was passed creating a Fisheries Enhancement Revolving Loan Fund within the Department of Commerce and Economic Development. Over the years, a variety of other provisions were passed to assist in the construction and operation of hatcheries. These include such things as property tax exemptions, the granting of special harvest area entry permits to PNP hatchery operators for harvesting of their own broodstock and cost-recovery fish, exempting these broodstock and cost recovery fish from salmon enhancement taxes, and allowing the state to contract the operation of state hatcheries to regional associations.

Currently the state operates 12 hatcheries throughout the state, and PNPs operate 25 hatcheries, of which 4 are state-owned facilities. Hatchery fish represented 24 percent of Alaska's commercial salmon harvest in 1990. The FRED Division maintains two pathology labs, one genetics lab, one limnology lab, and a coded-wire tag processing lab. The Division also provides technical and management assistance to the PNP hatcheries. While PNPs tend to focus on production for the commercial fishery, FRED hatcheries emphasize research, some production of sport fish species, and experimental farming of shellfish and aquatic plants.

A review of legislative history reveals that many facets of the hatchery program which have evolved over the past two decades, such as financing, related fisheries management issues, and biological concerns, were not foreseen or were only briefly acknowledged or discussed by the Legislature during the initial stages of development of the program. The record does reveal legislative intent in some broad areas, but it appears that many current questions and concerns regarding the role and future of hatcheries will have to be addressed without benefit of clear statutory or historical direction.

Chapter III

PRODUCTION POLICIES AND TRENDS IN ALASKA AND WORLDWIDE

In 1980, Alaska salmon harvests accounted for 41 percent of world salmon supply. By the end of 1990, wild and enhanced Alaska salmon accounted for just 31 percent of the world supply. This occurred, despite the 50 percent increase in Alaska's production during the same period, as a result of the dramatic increase in farmed-salmon production. Farmed-salmon production nearly doubled between 1988 and 1990, increasing from about 310 million pounds to over 600 million pounds. In 1990, farmed salmon composed about 30 percent of world salmon production, up from a mere one percent in 1980. The increased supply of salmon on the world market has lowered prices. Lower salmon prices and rising operating costs have brought economic hardship to salmon farming operations worldwide, although many farms remain competitive. Lower prices have also adversely impacted commercial salmon-fishing operations worldwide.

One interesting development in the salmon farming industry is that the glut of salmon on the world market has forced many salmon farmers to freeze their product for later resale. This trend could increase the competitiveness of Alaska frozen fish since it eliminates the perceived "fresh versus frozen" advantage of farmed fish.

The countries and regions which commercially harvest the largest quantities of ***wild and hatchery*** salmon are the United States (Oregon, Washington and Alaska), Canada (British Columbia), Japan and the U.S.S.R. Other areas have experimented with salmon ranching, but as yet produce few fish. Major salmon-farming industries are located in Norway, Scotland, Chile, U.S. and Japan. Iceland, the Faroe Islands, Ireland, Australia, New Zealand and France also farm salmon but are not considered major producers.

CHAPTER IV

FISHERIES MANAGEMENT ISSUES

The success of the state's enhancement program has made managing Alaska's salmon fisheries more complicated. Much of this research project was initiated by a request from the Board of Fisheries to provide clearer legal and policy direction on the issues of managing fisheries for a wild stock priority, providing for broodstock, and providing for cost-recovery fisheries. These three issues encompass a number of legal questions and are addressed in Chapter V, Legal Issues. In this chapter a variety of other management issues are discussed.

MIXED-STOCK FISHERIES

A fundamental issue facing fisheries managers is how to control fishing effort in mixed-stock fisheries composed of both hatchery and wild stocks. The predominant management concern is that the weakest stocks will be overfished. In cases in which hatchery productivity is significantly greater than natural stock productivity, wild stocks face the risk of being depleted. In cases where hatchery stocks are smaller, these stocks run the risk of being lost among the wild stocks. Smaller stocks are more likely to be in danger of depletion in mixed-stock fisheries because there is a tendency to optimally harvest the larger stocks before quality declines in terminal fisheries.

With large scale hatchery enhancement, ADF&G's Division of Commercial Fisheries is concerned that the additional costs of managing mixed stock commercial fisheries composed of wild and hatchery stocks are not always accounted for in the planning and operation of hatchery facilities, and fisheries managers are often not given adequate funds to properly manage what can become a very complicated fishery.

QUALITY

State law requires that fish returning to hatcheries and sold for public consumption be of comparable quality to fish harvested by commercial fishermen in the area. Prince William Sound is the major focal point for the issue of managing hatchery and wild stocks to optimize quality and marketability.

During the planning process for the Prince William Sound hatcheries, the Basic Management Plans that addressed the harvest of hatchery fish were developed cooperatively by the department and hatchery operators. ***Returning adults were to be primarily harvested in terminal areas, thereby minimizing harvest conflicts with wild stocks.*** Additional harvest management costs were not considered under this strategy. Initially, fish quality was not an issue as terminally caught fish were of high quality. However, as the program grew, processing capacities became fully utilized, sometimes forcing delays in harvesting terminal fish. Such delays resulted in poorer quality fish, and thus, the demand to harvest fish farther away from terminal areas. This issue was highlighted last season in Prince William Sound.

During discussions in 1991 of Governor Hickel's Salmon Strategy Task Force, it became apparent that there is no definitive information on how close to their spawning areas salmon can be harvested without sacrificing quality. ADF&G has suggested a research project be funded to analyze salmon quality at various distances from their spawning areas in an effort to determine how best to manage fishing effort to produce a top-quality and marketable product.

TAGGING NEEDS

Since hatchery-produced fish often complicate fisheries management, a way to simplify management is to determine the mix of hatchery and wild stocks in a mixed-stock fishery. For most mixed-stock fisheries composed of hatchery fish, an adequate program of tagging, recovery and analysis is required.

The tagging method most commonly used now is the coded-wire-tag (CWT). However, otolith marking is seen as the most viable mass marking technique on the horizon. The benefit of otolith marking is that virtually ***all*** hatchery fish can be marked at the same time. FRED Division is also actively pursuing genetic stock identification (GSI) research and applications using both protein electrophoresis and deoxyribonucleic acid (DNA) analysis. ADF&G has obtained funds for a new GSI lab and is now seeking funds for a new tag lab.

The extent of any particular tagging program is determined by funding. The general assumption is that the people who tag the fish pay for the tagging. In the case of hatchery operators, that usually means the state or the PNP operator. However, the greater expense lies with the recovery and analysis of tags by the state, and the issue of who pays for that portion has never been resolved. Commercial fisheries managers would like to see more tagging to enable increased management precision. The Board of Fisheries would also like to see additional tagging in order to provide information for allocation disputes.

FRED Division is informing hatchery operators that new increments of hatchery production will be permitted with a requirement that the operator pay for tagging and analysis. Whether or not to require that of existing production is being debated. Some people, including some members of the Board of Fisheries, advocate for a requirement that all hatchery production be categorically tagged and analyzed. However, existing operations have permits that do not require tagging. These operations were planned, permitted and funded without accounting for tagging in their costs. It is likely that imposing a tagging requirement on permitted facilities would be subject to legal challenge.

Another issue, however, is whether an all encompassing tagging requirement is necessary. In some cases, a multi-year tagging study to show migration patterns and run timing would be sufficient. In other cases, where tagging is intended for in-season management, a large tagging program would need to be maintained. Not all hatchery production results in complicated, mixed-stock fisheries that would necessitate extensive tagging.

The question has also been raised concerning the extent of tagging or marking of natural stocks, and whether the current level is sufficient to provide the necessary information in mixed-stock fisheries composed both of hatchery and wild stocks.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Development of a state policy on managing mixed-stock fisheries composed of hatchery and wild stocks.

- Requiring hatchery production to have tagging, recovery and analysis programs. This could range from a blanket requirement for all production to site-specific requirements.

- Development of a policy regarding funding for tagging, recovery, processing and analysis.

- Funding a study to analyze salmon quality at various distances from terminal streams to determine the effect of fishery management effort on product quality and marketability.

- Direction to the Board of Fisheries on how to factor managing for quality into fisheries management plans.

- Funding research and development of new tagging and marking techniques suitable for mass marking.

- Clarifying the roles and uses of tagging---for biological information, allocation, or management purposes.

- Expanding tagging and stock identification studies of wild fish stocks for the purpose of comparing wild and hatchery stocks.

UPDATE: In May 1992, the Alaska Legislature passed legislation (HB 541) requiring the Board of Fisheries to develop a mixed stock fisheries policy. Development of such a policy is currently underway.

Chapter V

LEGAL ISSUES RAISED BY BOARD OF FISHERIES

The Board of Fisheries ("board") has expressed to the legislature its concern over perceived ambiguities in the Alaska statutes relating to wild stock and hatchery fish management. ***One problem is that there is no clear statutory policy for the board to follow when it must make decisions that would favor wild stocks over hatchery fish or vice-versa. An additional problem is that the statutes are unclear about the state's duty to provide for hatchery broodstock and cost recovery, and about the hatcheries' obligation to contribute to the common property fisheries.***

The Alaska Statutes contain only two direct references to wild stock protection from hatchery-related dangers: AS 16.10.400(g), which requires the commissioner, during the development of a comprehensive regional plan and before a hatchery permit is issued, to determine that such an action would not jeopardize wild stocks; and AS 16.10.420(g), which directs the department to require, as condition of a permit, that the hatchery be located in an area where "reasonable segregation" from wild stocks occurs.

The board is concerned that these statutes protect wild stocks only prior to the start of a hatchery operation. This raises the inference that, once a regional plan is completed and/or a hatchery permit is issued, wild stocks no longer enjoy a statutory protection from hatchery operations.

Article VIII, sec. 4 of the Alaska Constitution ("Sustained Yield") states:

> Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses.

The board was created "for purposes of the conservation and development of the fishery resources of the state." AS 16.05.221. The Alaska Supreme Court has stated that, "'conserving' implies controlled utilization of a resource to prevent its exploitation, destruction or neglect" and that " 'development' connotes management of a resource to make it available for use." Kenai Peninsula Fishermen's Coop. Assn. v. State, 628 P.2d 897, 903 (1981).

ATTORNEY GENERAL OPINION

In an August 1990 opinion letter to the commissioner of the Department of Fish & Game, assistant attorney general Stephen White concluded that the board had the authority, and was in fact directed by law, to manage for hatchery broodstock. He further concluded that the board had the power to manage for cost recovery, but that it was not required to do so. He based these conclusions in part on the unstated assumption that the constitutional "sustained yield" requirement applied to hatchery fish. This assumption, coupled with the board's statutory charge to "conserve" the fishery resource, formed the basis for White's conclusion that the board was required to manage for broodstock.

White's conclusion that the board has the authority to manage for cost recovery was based on the board's statutory authority to "develop" the resource and to allocate among various user groups. Although hatchery operators are not specified on the list of user groups for which the board may allocate, AS 16.05.251(d), White concluded that the board had the power to make such an allocation by treating hatchery operators as a "subgroup" of commercial users. He noted that the Alaska Supreme Court, in Meier v. State, 739 P.2d 172, 174 (1987), has upheld a board allocation between two subgroups of commercial users.

OPINION RESPONSES

The White opinion generated two critical responses. The first was from ***Juneau attorney Michael A.D. Stanley, in a February 1991 letter to the Southeast Alaska Seiners. Stanley argued that the "sustained yield" clause may not apply to hatchery fish for a number of reasons.*** First, because humans play such a significant role in the development of hatchery fish, there is some question whether the framers of the constitution would have considered them "natural" resources "belonging to the state" as those terms are used in article VIII. Stanley then points to AS 16.10.440(a), which provides that hatchery fish are to be treated "in the same way as fish occurring in their natural state until they return for harvest by the hatchery operator." He argues that the "in the same way" language indicates the legislature did not view hatchery fish as already subject to article VIII.

Stanley also takes issue with White's conclusion that hatchery operators could receive a cost recovery allocation as a subgroup of commercial users. He asserts that the definition of "commercial fishing," AS 16.05.940(5), would have to be "strained" to include hatchery operators, and that such a broad reading would allow other inappropriate users (such as salmon derby operators) to be considered as a subgroup. He also notes that the definition of "commercial fisherman," AS 16.10.940(4), contemplates a "natural person," not a nonprofit corporation.

Finally, Stanley asserts that only the department, not the board, can make an allocation of fish for hatchery operators. He argues that AS 16.10.440(a), quoted above, allows for harvest only at an area designated by the **department**, and only after the hatchery fish have travelled through the common property fisheries. Stanley argues that for the board to decide otherwise would be a circumvention of the existing statute.

The second opinion that questioned assistant attorney general White's conclusions was from Legislative Counsel George Utermohle, in an April 8, 1991 letter to Senator Dick Eliason. He argues that, if the legislature had intended for hatchery fish to be managed on a sustained yield basis, it would have used the phrase "belonging to the state" when it wrote AS16.10.440(a), quoted above. Utermohle reasons that the legislature intended hatchery fish to be treated as if they were a part of the common property resource, but only until they return to the designated harvest location; at that point, the hatchery operator may harvest the fish. Utermohle asserts that this language "suggests some form of lingering private property interest in hatchery fish by the hatchery operator," and indicates that the fish do not "belong" to the state for purposes of sustained yield.

Utermohle also argues that if hatchery fish belong to the state, it does not mean they necessarily must be managed for sustained yield. He points out that the sustained yield principle is always "subject to preferences among beneficial uses." Citing commentary and minutes from the Alaska Constitutional Convention, Utermohle asserts that the delegates understood this qualification to mean that the state "could make reasoned decisions to prefer certain renewable resources over other renewable resources to achieve a more beneficial public purpose." He concludes that this "may permit the state to harvest hatchery fish without providing for sustained yield;" and points to AS 16.10.430(b), which allows the termination of a hatchery operation "in the best interest of the public, if the adverse effects of the operation are irreversible and cannot be mitigated."

The Stanley and Utermohle opinions generated a vigorous and lengthy response from Anchorage attorney A. William Saupe, contained in an October 17, 1991 opinion letter to the president of the Prince William Sound Aquaculture Corporation (PWSAC). Saupe concluded that any regulation significantly restricting PWSAC's broodstock and cost recovery practices would be inconsistent with existing statutes and with the Alaska Constitution. He further concluded that legislative history suggests the board was never intended to have the power to limit hatchery production.

Saupe points to the legislative history compiled by Linda J. Snow of the Legislative Research Agency as evidence that the legislature intended to assert state ownership of hatchery fish, and relies on statements made by several legislators and lobbyists to that effect. He also cites commentary from the framers of the constitution which states that the sustained yield principle is applicable to "plant and animal life subject to the immediate control of the state." Saupe argues that hatchery fish are so subject and therefore must be managed for sustained yield.

He answers the "beneficial use" argument by asserting that article VII, sec. 15, which speaks to the "efficient development of aquaculture in the state," indicates the importance and value of hatchery operations to the state; he also argues that hatcheries, specifically PWSAC's, would be seriously harmed if broodstock harvest was curtailed.

Saupe also points to "an extensive web of statutory provisions that evidence an unwavering legislative intent to sustain and expand hatchery operations through hatchery harvest," as evidence of the legislature's belief that harvests are necessary and beneficial. Among these provisions: AS 16.10.443, which requires the department to assist permit holders in the operation of their hatcheries; AS 16.10.450(a), which contains certain expenditure requirements for hatcheries that sell salmon or salmon eggs after harvest; AS 16.43.420, which allows for the sale of fish caught under the authority of a special harvest area entry permit; and AS 16.10.430(b), which allows sale, but not release, of fish during the period of time that a hatchery operation is being terminated; AS 16.05 020, which requires the commissioner to "improve and extend" the fisheries of the state. Saupe concludes that the cited statutes, and legislative history, demonstrate the legislature's intention that cost-recovery harvests be the primary method of funding private nonprofit hatchery operations.

Saupe also takes issue with Michael Stanley's questioning of the board's authority to allocate for cost recovery. Saupe argues that the language of AS 16.05.440(a), quoted above, applies only to the time and location of a special harvest and not to allocation. To support his conclusion, he points also to legislative history indicating approval of board authority to regulate hatchery harvests, as well as to provisions of the Limited Entry Act that subject entry permit holders to board regulations.

On the question of board restrictions on local hatchery production, Saupe is less certain. He cites evidence to the effect that the legislature did not consider such restrictions during the time the private nonprofit hatchery system was put in place; and he takes the position that AS 16.10.440(b), which allows the board to amend hatchery permit terms relating to source and numbers of salmon eggs, was intended by the legislature to relate only to harvests and not to limiting hatchery production. On the related question of the board's ability to limit hatchery production on a regional basis, Saupe acknowledges that the answer is unclear, but he asserts that such a policy would conflict with many statutes already cited, and with the constitutional provisions relating to sustained yield and promotion of aquaculture.

CONCLUSIONS

1. There is no specific statutory mandate directing the board to give wild stocks preferential management treatment relative to hatchery raised fish.

2. The Alaska Constitution may require that hatchery fish be managed to allow for broodstock and cost recovery by the hatcheries, but that requirement may be invalidated by a determination that the sustained yield of hatchery fish is not as "beneficial" a "use" of the fishery resource as that of protecting the health of the wild stocks.

3. Existing statutes appear to allow the board to allocate fish to hatcheries for broodstock, but are less clear as to the authority for cost recovery.

4. Existing statutes are not clear on the board's authority to restrict hatchery production on a local or regional basis.

OPTIONS FOR POSSIBLE CONSIDERATION:

•Placing a wild stock priority into state statutes; or alternatively, making the status of wild and hatchery stocks of equal priority, or leaving the statutes ambiguous.

•Clarifying in state statutes whether or not the Board of Fisheries is required to provide for hatchery broodstock or for cost-recovery fisheries.

•Clarifying the Board of Fisheries' authority to restrict hatchery production.

UPDATE: In May 1992 the Alaska Legislature responded to the concerns described in this chapter by passing SB 457, establishing a wild fish stock priority.

Chapter VI

PLANNING AND PERMITTING PROCESS

A major element of the statewide salmon enhancement program is the planning and permitting process.

CURRENT PLANNING AND PERMITTING PROCESS

The Department of Fish and Game (ADF&G) is responsible for planning enhanced salmon production which is conducted on a regional basis throughout the state. Regional aquaculture associations have been formed in some regions to plan and implement enhancement projects. ***Regional Planning Teams*** (RPTs), composed of department personnel from the fisheries divisions and representatives from the regional aquaculture associations (or local fishermen if there is no association), are charged with developing long-term comprehensive salmon production plans. The state also involved the private sector in the enhancement effort through private nonprofit (PNP) corporations which can plan and build hatcheries. Those PNPs that are not part of a regional aquaculture association are referred to as "Mom and Pop" operations.

The RPTs not only develop the comprehensive salmon plans, but also review and comment on all hatchery permit applications, annual hatchery management plans, and annual reports. Each hatchery enhancement project is reviewed, based on some relatively consistent criteria:

- Will the hatchery make a significant contribution to the common property fishery?
- Does the proposed project allow for continued protection of natural stocks?
- Is the proposed project compatible with the comprehensive plan?
- Does the proposed project make the most appropriate use of the site's potential?

The PNP permit application process is rigorous and includes substantial review, as well as a public hearing and full review by state and federal agencies through the coastal zone review process. Even in a best-case scenario, the review and approval process of a permit application takes at least six months.

Fish released by hatchery operators are available for common use 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 of hatchery special harvest areas. This is the basis for the board-regulated Fish Transport Permit process (see Biological Issues chapter), establishment of hatchery special harvest areas, and board-approved terminal harvest area plans. The statutes also appear to give the Board the authority to limit or control production at individual hatcheries based on egg-take for broodstock. This authority has never been used, and there is a strong difference in opinion as to whether or not the Legislature actually intended the Board of Fisheries to regulate hatchery production, or instead, to regulate the taking of eggs from wild stocks for hatchery production.

A ***Basic Management Plan*** (BMP) is developed as part of the actual permit. Marking programs for hatchery-produced fish can be required in the hatchery permit and BMP. Tagging is usually considered optional, unless during the permit or permit alteration process fisheries managers specify the need for special in-season management capability. When a permit is approved and operational, an ***Annual Management Plan*** (AMP) is developed for each year of operation.

FISH TRANSPORT PERMITS

The possession, transportation or release of live fish and their reproductive products (eggs) into the waters of the state requires a ***Fish Transport Permit*** (FTP) from ADF&G. The FTP permit application covers only one specific operation and is quite detailed. The application is intensively reviewed by the regional supervisors of the FRED, Commercial Fish and Sport Fish Divisions, the FRED pathologist and principal geneticist, as well as the FRED chief of technology and development and the FRED director. A signature page is attached to the actual permit which includes recommendations and comments. The permit is then approved or disapproved by the commissioner of ADF&G. The potential for disease and genetic impacts are the primary considerations in the FTP review process.

FISH RESOURCE PERMITS

ADF&G is currently developing a policy on ***Fish Resource Permits*** (FRP). The FRP was previously called a scientific/educational (sci/ed) permit. This policy is being developed as a result of a lack of standards for the scientific and educational projects allowed. Under the proposed policy, Fish Resource Permits will be issued with the stipulations of no commercial activities, no human consumption, and no sale of the species. These permits are classified into collecting permits for scientific or educational purposes, holding permits for either exhibition or scientific research, and limited propagation permits for various scientific or educational purposes, including mariculture site suitability.

PROBLEMS AND ISSUES

1. Lack of statewide goals and objectives for enhancement program.

The original goal of the enhancement program was to rehabilitate the state's depressed salmon fisheries. This goal has essentially been met, with the numbers of Alaska's wild and hatchery fish at an all time high. Other than the problems of marketing and price, most of the state's salmon fisheries are no longer depressed. ***The state does not have a clearly defined policy for future management and development goals for hatcheries and other enhancement efforts that goes beyond increased production.***

2. Regional or Statewide Planning.

State law directs salmon production planning to be done on a regional basis. Little comprehensive statewide planning is done, with only minimal interaction between regions of the state. At the time these provisions were enacted, it was not envisioned that hatchery-produced fish would become such a large proportion of the statewide harvest. ***Fisheries managers argue that the state needs a statewide planning policy that will take into account the potential impacts of the production of one region on***

another, as well as closely scrutinizing potential management problems and marketing feasibility. Others involved in the industry argue that regional differences are so unique and contentious, that such a statewide process would be futile.

The Board of Directors of the United Fishermen of Alaska (UFA) in January 1992, requested the FRED Division to involve all RPTs in a statewide review process of hatchery production. No action has been taken on that request.

3. Funding and support for planning.

Fishermen, hatchery operators, and state fisheries managers agree that the RPT planning process provides an important forum for discussing and resolving difficult issues on an ongoing basis.

However, ***state support for planning has declined since the early 1980s*** when FRED had a budget of over $500,000 for grants to aquaculture associations. Despite the need for more rigorous planning due to increased enhanced production, FRED planning staff has declined from two to one and a half positions. These positions coordinate all enhancement efforts statewide, including state facilities, provide technical assistance to the PNPs, and plan new ventures. ***Budget reductions have forced state planners to shift priorities from plan development and implementation to plan maintenance.*** Those involved in planning say the current funding level is inadequate for FRED to properly oversee the functions of the 37 hatcheries in operation in Alaska. As a result, they believe many more conflicts and issues will develop that should have been resolved early in the process.

RPT members also complain that the cutback in funds for planning has limited their contribution to a cursory discussion and approval of permit changes. If a hatchery requests a change in a permit, they often have to wait six months or longer to be considered because funds are not available for some RPTs to meet more than twice a year.

4. Composition of Regional Planning Teams

Although many people believe the regional planning team (RPT) process is a good one if adequately staffed and funded, there are others who believe that the entire structure of the RPT should be changed. A frequent complaint is that the composition of the RPT is heavily weighted towards the commercial sector of the fishing industry, without sufficient representation of subsistence and sport fishing users, community and regional governments, environmentalists, and the general public. These critics argue that in order to have a truly ***balanced*** decision, all the varied interests of the region need to be adequately represented. Some RPTs have tried to address this complaint by broadening the composition of the team to include all interested groups.

Another, more fundamental concern is that ADF&G managers are usually out-numbered on the RPTs. As a result, the group can pressure department managers into approving projects that should probably be denied. Department personnel who raise future management concerns are under considerable pressure to be a ***positive*** presence in the RPT process, which in some cases, translates into withdrawing or modifying their objections without these concerns being adequately addressed. On the other hand, concern has also been expressed that department managers sometimes have a strong, anti-hatchery bias that can influence their management recommendations.

There is also the concern that the non-Fish and Game members of the RPT may not be sufficiently capable of evaluating and making decisions on issues that are increasingly technical in nature.

5. Allocation issues.

The RPT does not have allocation authority; that responsibility is delegated by state statutes to the Board of Fisheries. ***Without the ability to consider allocation issues as part of the permit review process, ADF&G may approve a hatchery permit that could create future allocation problems.*** By the time the Board of Fisheries begins to consider allocation problems resulting from hatchery production, millions of dollars may have been invested through state loans. In addition, allocation conflicts over hatchery-produced fish may eventually require tagging programs as part of their resolution. The question of tagging--and who should pay for it--is one that is more easily addressed early in the planning and permitting process.

Recent developments seem to indicate a change for the future. ***In 1988, the Board of Fisheries charged the Prince William Sound Aquaculture Corporation (PWSAC) with development of an allocation plan for enhanced stocks in Prince William Sound.*** After an intense planning effort and several drafts, PWSAC was able to come up with an allocation scheme that all user groups and the department could support. The allocation plan was approved by the Board of Fisheries in 1991 and was in effect this past fishing season. Using the success of PWSAC as a model, the Board of Fisheries has also directed the two Southeast regional aquaculture associations (NSRAA and SSRAA) to develop an allocation plan for hatchery stocks by 1993.

6. Management issues.

Another complaint is that regional comprehensive salmon plans often focus exclusively on production goals for a hatchery, but provide little specific information on fishery management. FRED now requires an initial **Management Feasibility Analysis** (MFA) be completed before a final application is submitted. The MFA covers the basics of siting, species, timing, and magnitude of production, and is developed by the Commercial Fisheries and Sport Fisheries Divisions to avoid potential management problems. FRED planners believe that they have never permitted a hatchery or enhancement project that fisheries managers did not initially approve.

7. Uniform review.

State hatcheries and projects are not subject to the same permitting requirements as PNPs. Some fishermen believe that state projects cause the most allocation, management, and potential biological problems because of the lack of this additional layer of scrutiny. They would like to see permits required for state hatcheries and projects, as well as for PNP projects. FRED Division believes adding this requirement is unnecessary because of the many other layers of review these projects receive.

8. Criteria to show public benefit.

Four criteria must be considered by the RPT to determine if a permit application is in compliance with the regional comprehensive salmon plan:

- the contribution the proposed hatchery would make to the common property fishery,

- the provisions for protecting wild stocks from any adverse effects which may originate from the proposed hatchery,

- the compatibility of the proposed hatchery with the goals and objectives of the comprehensive salmon plan for the region, and

- whether the proposed hatchery would make the best use of the site's potential to benefit the common property fishery.

Critics say these criteria should be expanded to consider other public benefits and costs.

9. Operation performance reviews and permit revocation.

State managers and RPT gear group representatives are also concerned about ADF&G's authority over hatcheries that are out of compliance with state laws, regulations, and permit requirements. ***With the potential risk of impacts on the state's common property fisheries, managers and some RPT members believe a mechanism to allow for the timely revocation of a permit is necessary.***

10. Hatchery Siting Privileges

If a region has an organized aquaculture association, that association, under state statutes, has the preference rights to all potential hatchery sites in that region. Non-association PNPs (Mom and Pops) have expressed concern that giving priority use of potential to future sites to an association is not good public policy. The Mom and Pop operators believe that any unused hatchery sites should be available to both associations and non-association PNPs.

11. Canadian evaluation model.

The Canadian government is considered to have a model evaluation program of its national salmon enhancement program. The first evaluation project began in 1985 and concluded that there was not enough production and biological data available to carry out a proper program evaluation. The program audit branch then designed the optimum evaluation framework and determined what kind of data would be needed. These data included biological and production information, as well as an analysis of economic costs and benefits. With that data in hand, program auditors are now preparing to spend a year reviewing the entire program, with a final report due in March 1993. Federal funds are being used for this project, although university staff and consulting firms are conducting the actual evaluation.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Working with the public and user groups to develop statewide goals and objectives for the state's entire fisheries enhancement program.

- Directing FRED Division to develop a program to implement these goals and objectives.

- Declaring a moratorium on further hatchery development or increased production until the Legislature's economic cost-benefit studies are complete and a full assessment of the hatchery program can be made.

- Development of a statewide planning process.
- Development of a statewide production plan.
- Requiring FRED to develop a comprehensive annual report that not only compiles production figures from state and PNP facilities, projects, and current management regimes, but also includes future production and management plans.
- Evaluation of the composition and procedures of the RPT to determine if changes in the RPT structure are necessary.
- Expansion of state statutes to require all hatcheries, including state facilities, to comply with a single planning and permitting process, with the same requirements for monitoring and review.
- Widening the scope of RPT review, including recommendations for allocation of enhancement production.
- Providing adequate funding for planning.
- Reviewing the required Management Feasibility Analysis to determine if it needs to be a more comprehensive review.
- As part of permit review and solicitation of state loans, consideration of adding new criteria to show public benefit, including marketability, a detailed cost/benefit analysis instead of a financial feasibility analysis, a more specific indication of the "significant contribution" to be made to the common property fishery, and some kind of environmental assessment.
- Providing concrete direction for the timely performance review of PNP hatcheries and a more workable mechanism for closing or converting hatcheries not making a "significant" contribution to the common property fishery.
- Exempting the alteration, suspension or revocation of an enhancement permit for violations from the Administrative Procedures Act.
- Instituting a regular review process similar to the Canadian model.
- Clarifying Board of Fisheries authority to regulate hatchery production levels.
- Re-evaluation of the policy of giving regional aquaculture associations the preference rights to develop future hatchery sites in the region.

Chapter VII

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. Top fisheries biologists, ecologists and geneticists from the United States, Norway, Sweden, the Soviet Union and Japan were present at the Cordova workshop. As a follow-up to the workshop, the group produced an interim 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, overfishing, and large-scale hatcheries has led 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 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 largely results from insufficient data and research, and at times, professional bias. 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 these studies.

THE GENETIC EFFECTS OF HATCHERIES

Most scientists agree that it is essential to have healthy wild stocks 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 extent 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 variables involved in imprinting, and the effects of interbreeding 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. However, the concern is that intermingling may reduce the fitness of the locally adapted populations.

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 nearshore marine 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 was reported throughout the Pacific region in 1991, but various factors may be responsible. Since 95 percent of the growth of salmon occurs at sea, 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. More information is needed on the effects of predation and competitors.

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. Norway has had considerable problems with disease transmitted by farmed salmon that have escaped and mixed with wild stocks.

Active fish pathology laboratories are maintained by the FRED Division in both Juneau and Anchorage. Their basic function is to implement policies and procedures that guard against the spread of fish and shellfish diseases in Alaska. Reviewing fish transport permits in order to reduce the occurrence of disease is a major task of the labs, as is examining each broodstock for disease prior to its use in a hatchery.

STATE GENETICS PROGRAM AND POLICY

The state genetics program is intended 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. The state's fish genetics policy, considered to be one of the most stringent in the world, was last revised in 1985, and will be reexamined and updated this year.

Alaska's genetic policy contains guidelines and restrictions intended to protect the genetic integrity of wild stocks. The ***goal*** is to maintain adequate genetic variability, ensuring that the enhanced stock will be able to adapt to changing environmental conditions.

Geneticists have two primary concerns in protecting wild stocks and implementing a successful enhancement program. The first is possible genetic impacts due to gene flow between wild or enhanced stocks; the primary concern being, of course, for wild stocks. The second concern is the loss of genetic variation within or among stocks. Both impacts can potentially cause the reduction of total fitness in wild stocks and hatchery broodstocks. These problems are addressed in the policy's three main topic areas: stock transport, protection of wild stocks, and the maintenance of genetic variation.

Since specific knowledge of salmon population genetics and the genetic impacts of salmon enhancement on wild stocks was limited, the 1985 genetic policy was based primarily on information from agricultural genetics and research on other species. As a result, the policy contains guidelines that are rather flexible. The policy suggests that because scientific knowledge is limited, fish transport should be evaluated conservatively. For example, if genetic similarity decreases with distance, arbitrary limits must be set on the distance a stock can be transported. For that reason, the Fish Transport Permit process is the prime regulatory tool in the genetic policy. ***ADF&G is attempting to clarify some of the*** *flexible guidelines in the revised policy by incorporating knowledge gained from recent studies of the population genetics of salmonids.*

The genetic policy also acknowledges that all salmon runs 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. However, the policy says that the concept of "significant stock" only relates to the size of a fish population in the context of local importance and use. A population that would be considered insignificant in size in one region, may be of vital importance in another region.

OPTIONS FOR POSSIBLE CONSIDERATION:

Although a report of recommended management actions resulting from the Cordova workshop is expected in late February, some preliminary options for consideration include:

- Evaluation of how well the current hatchery program protects wild salmon from possible negative effects of hatchery salmon. Such a review would help policy makers determine the risk of various alternatives for the future of Alaska's hatchery program.

- Increasing the amount of genetic monitoring required of hatchery operators, and directing ADF&G to continuously review and analyze resulting data statewide.

- Considering creation of genetic sanctuaries that are "enhancement free".

- Obtaining consensus about research priorities concerning the interaction of hatchery and wild fish in Alaska, coordinating future studies, and deciding how and when to apply the results of those studies to current management practices.

- Conducting research to define the minimum conditions for imprinting for remote release programs.

- Review of current and future programs for their compliance with the state genetics policy.

- Placing greater emphasis on management concerns in the permitting process in order to protect wild stocks.

- Re-examination of escapement goals in order to maximize wild productivity.

- Increased use of marking and tagging programs to monitor interactions between hatchery and wild populations.

- Policy development to minimize inbreeding and straying, including an evaluation of remote releases.

- Treating a remote release site as a de facto hatchery site in terms of broodstock and hatchery site guidelines, even if all fish are expected to be harvested.

- Identification of genetic population structures to determine what populations are genetically distinct.

- Survey of populations prior to any enhancement activity to provide a baseline for subsequent genetic monitoring. Evaluation of genetic consequences of hatchery production on adjacent populations during phased-in expansion, with production increases halted if adverse impacts are noted.

- Monitoring wild and hatchery stocks to determine extent of straying and intermingling.

- Continuing to build on cooperative UAF, ADF&G and hatchery studies of environmental factors affecting regional-level production of salmon in southeast, southcentral and western Alaska.

- Funding a joint state and federal workshop on salmon ecology in Prince William Sound, using recently released oil spill research.

- Conducting research to determine impact of salmon harvest on other species such as crab, sea lions, sea birds, etc., which may compete for same food sources.

CHAPTER VIII

FUNDING OF THE ALASKA SALMON ENHANCEMENT PROGRAM

Sources of funds for the Alaska salmon enhancement program and projects include bond issuances, state general fund appropriations, salmon enhancement tax assessments paid by fishermen, state enhancement loans, and cost-recovery sales of fish.

STATE PROJECT FUNDING

Funding for the operation of the state salmon enhancement program and state project construction, operation, and maintenance has been primarily through state bonds and general fund appropriations to ADF&G, FRED Division. From FY 72 - 92, funding for the FRED Division totalled approximately $210.3 million, the majority of which was for salmon enhancement. Bond issues totalling $56.17 million were authorized by the 1976 and 1978 Legislatures, and overwhelmingly endorsed by voters, to fund the construction and operation of hatchery production and other enhancement projects in each region of the state. Of the $56.17 million in bond issues for FRED enhancement projects, $50.3 million was spent on hatcheries, while the remainder was used for other enhancement projects. State funding for FRED division construction of state facilities totaled approximately $24.8 million through FY 92.

FUNDING FOR PRIVATE NON-PROFIT HATCHERIES

Funding for PNP hatcheries is primarily through state loans, the salmon enhancement tax, and cost recovery sales of fish. To a lesser extent, the state has provided grants to some facilities and fishing organizations; these have totalled approximately $12.3 million.

Since 1977, a significant portion of the funding necessary for the implementation of salmon rehabilitation and enhancement activities by PNP corporations has been provided through the ***Fisheries Enhancement Revolving Loan Fund*** administered by the Alaska Department of Commerce and Economic Development (DCED), Division of Investments (AS 16.10.500-620). The loan program has gone through several modifications by the legislature, the most recent occurring in 1987. The maximum loan amount available for an individual project is $10 million at approximately 9.5 percent interest, with a payback period of up to 30 years. According to state statute (AS 16.10.525), payments and accrual of interest on these loans ***must*** be deferred for 6 to 10 years. Loans for non-regional aquaculture association projects have these same terms with the exception that the loan maximum is limited to $1 million. Loans are available for the purpose of planning, construction, and operation of salmon rehabilitation and enhancement projects, primarily salmon hatcheries. State regulations to implement these statutes were revised in 1992, but many hatchery operators still feel they are not flexible enough. This topic is being addressed by a legislative audit team.

The ***Salmon Enhancement Tax*** (AS 43.76.010-.015) is charged to limited entry permit holders who are members of qualified regional aquaculture associations. State law allows the associations to set enhancement tax rates at either 1 - 3 percent of the ex-vessel value of the salmon catch, subject to the vote of the membership.

Through November, 1991, $71.0 million has been borrowed by PNP corporations. Approximately $67.7 million (95 percent) of the $71.0 million principal balance is currently outstanding. Including state appropriations ($12.3 million), approximately $83.3 million has been provided in state loans and grants to PNPs. Another $46.2 million has been generated through enhancement tax assessments. To date, PNP operators have sold approximately $70.9 million worth of cost-recovery fish to help pay for hatchery operations. The amount and percentage of funding by category is shown below.

$71.0 million	35 percent	State Loans
$12.3 million	7 percent	General Fund Grants
$46.2 million	23 percent	Enhancement Tax Assessments
$70.9 million	35 percent	Cost Recovery Sales of Fish
$200.4 million	Total	

As can be seen, the private sector has provided over 58 percent of the direct funding for PNP operation and construction through self-imposed taxes and cost recovery sales of fish.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Requiring a more extensive public benefit-cost analysis before providing enhancement loans. This means that a project or facility expansion would not only have to be financially feasible--capable of paying back loans--but also provide net benefits to the public.

- Eliminating the statutory loan repayment deferment requirement on operating loans.

- Development of a mechanism for placing moratoriums on state enhancement loans for increased fish production. Consideration of a moratorium on loans until results of the Legislative Enhancement Program Review economic studies are complete.

- Implementing a requirement for more complete analysis of transfers of the operation of state hatchery facilities that includes factors such as upfront capital costs to state to expand or upgrade facility before transfer is accepted, fisheries management implications, increased need for cost recovery, and the impact on traditional common property fisheries.

- •Analysis of the enhancement tax program to determine 1) whether costs are distributed in proportion to benefits, and 2) the impact of a mechanism to allow specific gear groups to opt out of the program or pay in proportion to the enhancement benefits they receive.
- •Analysis of increasing the salmon enhancement tax so fishermen who benefit from the program will pay for more of the costs.
- •In light of declining state revenues and lower fish prices, development of an auditing mechanism to ensure that annual PNP operating costs, paid by loans, enhancement tax receipts and cost recovery, are "reasonable."
- •Development of a requirement that funds provided in treaty agreements for enhancement be used for fish production to the maximum extent possible. In addition, a requirement for a comprehensive feasibility analysis of using enhancement as part of treaty agreements could be considered.
- •Analysis of use of enhancement loan funds for operating funds versus capital investment

UPDATE: In June 1992, Senator Dick Eliason requested through the Legislative Budget and Audit Committee an audit of funding issues related to fisheries enhancement programs in order to respond to concerns raised during the review process. A final audit is expected in February 1993.

Chapter IX.

ECONOMICS

The Legislative review of the salmon enhancement program included a benefit-cost analysis of the program. This analysis was completed under contract to the University of Alaska, Fairbanks. ***Given recent low Alaska salmon prices and relatively dismal international salmon markets, the economic analysis was conducted to address questions such as whether Alaska enhanced salmon stocks are over-produced given current international salmon markets, the impact on Alaska regional salmon prices of additional enhanced production, the optimal species production mix, and the appropriate level of continued state fiscal support.***

The study consisted of four parts. First, a biological model (Collie, 1992) was used to estimate the returns of adult fish available for harvest under a variety of scenarios. Second, given the return of fish, an international demand model was estimated to predict the prices fishermen would receive at the ex-vessel level (Herrmann and Greenberg, 1992). Third, a fishing cost model was estimated to predict the producer's surplus in each fishery given the ex-vessel prices and returns of fish from the biological model (Boyce, 1992). Fourth, a survey of the hatcheries provided the costs of producing various levels of hatchery fish. The combined results of these four studies comprise the benefit-cost analysis of the salmon enhancement program. (Boyce, Herrmann, Bischak and Greenberg, 1992)

While the contractors have completed their work on the research, the public has not had the opportunity to review and comment on the results of the study. Therefore, the draft economics chapter, with options for possible consideration, and the final benefit-cost report economics chapter, with options for possible consideration, and the final benefit-cost report have been printed separately. That document, entitled "Legislative Review of the Alaska Salmon Enhancement Program, Draft Chapter IX, Economics", is available in the Legislative Library in Juneau.

Chapter X.

MARKETING

Following the precipitous decline in Alaska salmon prices in 1991, Governor Hickel formed a.Salmon Strategy Task Force to identify the problems facing Alaska's salmon fishing industry and recommend state actions to address these problems. A primary focus of the task force was salmon marketing. The task force recently finalized its recommendations. To avoid duplication with the task force's efforts, it was decided that the Legislative review of the Alaska salmon enhancement program would analyze the economic costs and benefits of the enhancement program and review past state salmon marketing efforts.

INTRODUCTION

The Alaska Seafood Marketing Institute (ASMI) was established in 1981 as a quasi-state corporation in the Alaska Department of Commerce and Economic Development (DCED). The institute's statutory responsibilities include:

- To conduct educational, research, advertising, and sales promotional programs to increase awareness of all species of seafood and their by-products that are harvested in Alaska.
- To develop quality specifications to enhance the high quality image of Alaska seafood worldwide, and to adopt recommendations for the handling of seafood from the moment it is caught until it is shipped to the marketplace.
- To prepare market research and product development plans for all species of seafood and their by-products harvested in Alaska.

State statutes prohibit ASMI from favoring any region, product, or processor. For that reason, ASMI uses "generic" marketing campaigns aimed at enhancing the sales of particular "species" of fish or broad product categories (such as canned or frozen) rather than specific products. Also, because it is likely to favor individual processors, ASMI does not promote new products.

ORGANIZATION

To accomplish its statutory mission, the ASMI organization consists of a board of directors, numerous committees, and a relatively small number of staff. Policy and program direction is set by the 18-member board of directors. The ASMI committee system is extensive with the largest portion being a system of marketing committees. The ASMI executive director is selected by the board of directors and permitted to hire additional staff upon approval of the board.

ASMI FUNDING SOURCES

A portion of ASMI's funding is derived from a self-imposed seafood marketing assessment. All fish processors who purchase annually $50,000 or more (ex-vessel value) of seafood pay an assessment of 0.03 percent of their total purchases. These assessments are collected in the state's general fund and are appropriated annually to ASMI. The balance of ASMI's funding is derived from state general fund and federal appropriations.

Federal funding, which has increased as a result of the Market Promotions Program (MPP) program, is restricted to international marketing efforts. ***State general fund appropriations and industry contributions are used primarily to fund domestic marketing efforts. Since these are declining, ASMI will have fewer resources for domestic marketing at a time when the domestic market has been identified by analysts as having the greatest potential for increasing sales of Alaska salmon.***

EFFECTIVENESS OF THE ASMI PROGRAM

When ASMI was established, the Alaska salmon industry provided most of the U.S. production and about half of the world production from wild and ocean-ranched salmon stocks. When Alaska was the dominant supplier, the generic marketing of Alaska salmon was relatively effective.

A recent Legislative Audit report evaluated whether there has been an increase in awareness of Alaska seafood since ASMI's inception. The Legislative Audit review of market research provided by ASMI concluded that increases had occurred in consumers' perception of Alaska seafood. In addition, consumers are more aware of Alaska as a seafood-producing region.

Despite these overall improvements in consumer perceptions and increased consumption of seafood, Alaska has lost a significant share of both the domestic and international salmon markets as a result of the tremendous growth in world farmed-salmon production. The dramatic rise in production and growing acceptance of farmed salmon as a source of fresh salmon represents the single greatest threat to the Alaska salmon market.

A significant problem is the fact that canned salmon production represents 59 percent of all of Alaska salmon sold in retail markets. U.S. per capita consumption of canned salmon declined 60 percent from 1980 to 1989, at the same time that harvests of pink salmon--the majority of which is canned--increased approximately 50 percent.

Analysts who are critical of ASMI's marketing programs maintain that the "generic" approach promotes all salmon, regardless of origin, because Alaska products are not clearly identified in the market. They argue that without brand identification and a quality assurance program to guarantee that Alaska salmon is superior, generic marketing may actually be helping Alaska's competitors.

LABELING OF ALASKA SALMON

A recent *Consumer Reports* article attacking the quality of seafood sold in the United States has caused considerable concern within the Alaska fishing industry. The article illustrates the problem of insufficient labeling of seafood products when sold in retail markets. Alaska does have a statute that requires that any farmed salmon sold in the state must be labeled that it is farmed and is from outside Alaska. The Alaska State Legislature has requested the Alaska delegation to introduce federal legislation requiring the labeling of all seafood products sold in the United States.

THE SALMON STRATEGY TASK FORCE RECOMMENDATIONS

The Salmon Strategy Task Force finalized its recommendations on January 24, 1992. These included:

Recommendations for Immediate Action. 1) ASMI should develop a budget and strategy for selling the existing inventory surplus of Alaska salmon; 2) processors and fishermen should initiate price negotiations early; 3) The University of Alaska, DCED, and ADF&G should provide the best possible information to fishermen regarding world salmon markets; 4) DCED should review Prince William Sound processing capacity; 5) DCED and the Alaska Commercial Fishing and Agriculture Bank (CFAB) should provide loan extensions as needed.

Mid-Range Recommendations. The mid-range recommendations include actions for product and market development, salmon quality, and marketing, and a review of ASMI's role.

Long-Term Recommendations. The long-term recommendations include the development of a strategic plan to help strengthen the fishing industry and its support sector.

ASMI'S SALMON RECOVERY PROGRAM

One of the recommendations of the Salmon Strategy Task Force was ASMI's Salmon Recovery Proposal. According to an ASMI briefing paper, the ***goal*** of the Salmon Recovery Program was to increase annual per capita U.S. salmon consumption from 1 to 1.5 pounds. The ***cost*** of the proposal was estimated at $10 million annually for five years, totalling $50 million.

ALTERNATIVE PROPOSALS TO INCREASE MARKETING EFFORTS

Proposed Changes to Alaska Statutes:

A number of pieces of legislation have been introduced recently to address the salmon marketing problem. The general intent of the proposals is to provide funding for the immediate increased promotion of Alaska salmon and to increase the voice of fishermen in those marketing efforts either through changes to ASMI or creation of a new salmon marketing association. No action was taken on any of these proposals in 1992.

- Creation of six regional salmon marketing committees and the Alaska State Salmon Marketing Association. Two fishermen from each committee would sit on the association. Funding for marketing efforts would be provided through a 1 percent marketing tax on value of salmon landed.

- Expansion of ASMI's statutes to allow for targeted development of Alaska salmon markets and product development.

- Imposition of a temporary one percent (1%) marketing tax on the value of salmon landed and increasing the ASMI Board of Directors by two positions that must be filled by commercial fishermen.

- Establishment of a temporary one percent (1%) salmon marketing tax and a committee within ASMI to provide fishermen with control over how the funds would be expended.

- Endowing the Alaska Fisheries Development Foundation to fund fisheries development research projects.

Development of a Salmon Marketing Council

Under the federal Seafood Promotion Act of 1986, after rigorous fisherman and processor review and approval, a salmon marketing council could be developed to increase the U.S. marketing efforts of salmon.

OPTIONS FOR POSSIBLE CONSIDERATION:

•Review of the state's role in the marketing of Alaska seafood, and salmon in particular, including a review of the ASMI program.

•Given that ASMI's generic approach to marketing was statutorily established prior to the significant increase in world farmed-salmon production, expansion of ASMI's statutes to reflect changes in world salmon markets. In particular, ASMI's marketing efforts could be expanded to include new product and market development, including targeting and distribution of salmon products at the wholesale and retail levels.

•Providing funding for ASMI's Salmon Recovery Proposal.

•Supporting the Salmon Strategy Task Force's recommendation that ADF&G review the impact of fisheries management practices on fish quality, especially related to the quality of cost-recovery fish harvested in terminal areas.

•Conducting a comprehensive analysis of ASMI privatization including whether 1) privatization would provide greater flexibility and possibly more effective marketing and 2) privatization would result in the loss of control over marketing activities to the detriment of Alaska and Alaska fishermen.

•Encouragement of the development of a national salmon marketing council.

CHAPTER XI.

OTHER ISSUES

A. USE OF ENHANCEMENT AS ENVIRONMENTAL MITIGATION

Hatcheries are sometimes built with the goal of mitigating environmental damage caused by such things as construction of dams and other projects, and water pollution. While the goal of environmental mitigation has been a driving force in salmon hatchery development in the Pacific Northwest, Alaska's hatchery system has been developed for fisheries enhancement, mitigation of the effects of overfishing, and offsetting reductions in fishing quotas due to treaty provisions.

However, Alaska law does contain several provisions regarding use of fisheries enhancement projects as a means of mitigating environmental damage. The primary one is the ***Fishways Act*** which can require the builder of a dam or other obstruction across a stream containing fish to provide and maintain a fishway or other device for fish passage; pay a lump sum to the state Fish and Game Fund; convey land and fund the construction, maintenance and operation of a fish hatchery, rearing ponds, buildings and other facilities; or agree to provide money to expand, maintain, and operate additional facilities at existing hatcheries.

Since passage of the Fishways Act of 1959, other environmental protection laws and regulations pertaining to fish habitat have been enacted setting water quality standards and regulating the types, locations, and designs of development projects. The *Anadromous Fish Act* (AS 16.05.870) is especially important as it spells out requirements for pre-approval of any projects which could potentially impact fish or fish habitat.

The construction of a fishway or spawning channel is frequently required in Alaska. ***Although the state rarely imposes the other provisions of the Fishways Act which require construction of hatcheries or monetary compensation, those provisions encourage modifications in project plans that will avoid the actual stream obstruction and serious risk to fish that would activate the very expensive mitigation measures.***

In other states and countries, where environmental protection measures have not prevented a project from damaging fish habitat, hatcheries have indeed provided enough fish to avoid the total destruction of fisheries. However, ***there is growing concern that when natural stocks decline to very low levels, hatcheries may actually cause the further depletion, even to the point of the extinction of natural stocks.*** These concerns are further addressed in Chapter VII of this report, Biological Issues.

It is important to consider how the federal Endangered Species Act (ESA) relates to the use of hatcheries for mitigating environmental damage. In the state of Washington, where hatcheries have been used extensively with mitigation as a goal, it is apparent that even very productive hatcheries cannot prevent the federal government from invoking the provisions of the ESA if wild stocks are determined to be endangered. In 1991 several Washington salmon stocks were listed as ***endangered*** or ***threatened*** by the National Marine Fisheries Service, which has jurisdiction over endangered species. Decisions regarding two other stocks are pending.

The Washington Legislature is considering legislation to address ESA salmon issues. These include salmon habitat, wild stock protection, tagging of hatchery stocks, and defining ***species*** or ***stocks*** of fish.

Declaration of a salmon stock as ***endangered*** can have enormous impacts on fisheries and local and state economies, even those which are far from the spawning area of that stock.

The ESA sets the parameters within which hatcheries can be used to mitigate environmental damage. ***Because of the Act, efforts to mitigate damage through hatcheries can result in the closure of fisheries if the hatcheries contribute to the further depletion of a stock.*** A preservation of wild stocks focus is necessary to avoid the impacts of the strict protective measures which can be imposed under the ESA.

In some instances, such as where dams have irreparably destroyed the habitat of a particular salmon stock, a carefully designed hatchery or other enhancement project may represent the only hope for survival of that stock. Thus, ***while the ESA serves as a warning against hatchery development that could deplete natural stocks, it also recognizes the potential usefulness of hatcheries in the ultimate survival of an endangered stock.***

The use of hatcheries to mitigate damage must be employed with the understanding that salmon which have been provided ***free*** and perpetually by nature, are being replaced by salmon that will initially and continuously cost money to produce. This cost, along with the possibility that hatcheries may harm remaining natural stocks, must be realistically evaluated in each case.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Re-evaluation of the state Fishways Act and Anadromous Fish Act in light of the provisions of the federal Endangered Species Act.
- Evaluation of whether specific consideration of potential consequences of the ESA should be required before the commissioner can pre-approve a project (under the Anadromous Fish Act) or approve of mitigation measures (under the Fishways Act).
- Tracking the current and upcoming debate and actions occurring in other areas, particularly the state of Washington, regarding environmental mitigation of damage to fish habitat. Determine the relevance of findings to Alaska.

B. ROLE OF ENHANCEMENT IN INTERNATIONAL TREATIES

U.S./Canada Pacific Salmon Treaty

After many years of negotiation, the United States and Canada signed a treaty in 1985 regarding the interception of Pacific Salmon. ***The primary goals of the treaty were to protect and rebuild depleted salmon stocks, assure the long-term viability of salmon stocks within the jurisdiction of the treaty, and bring equity by providing that each country receive benefits from the fisheries which are roughly commensurate with their respective production of salmon in the treaty area.*** Fisheries management guidelines for the region covered by the treaty (Oregon, Idaho, Washington, Southeast Alaska and British Columbia, Canada) are provided in a series of annexes to the treaty which are renegotiated on a regular basis. The annexes establish baseline-harvest numbers for many areas but the authority over allocation of fish between user groups within specific areas is maintained by the respective states, provinces, and tribes.

In 1983, a tentative treaty agreement was reached, but Alaska fishing groups found the provisions to be unacceptable and the treaty was not signed. Concerns centered on the concessions to be made by Alaska in the treaty. The reduction in the level of chinook salmon that Alaska trollers would be allowed to harvest was especially controversial. Key to the eventual acceptance of the treaty by Alaska was an offer by the U. S. federal government to give Alaska approximately $20 million for salmon enhancement to help offset impacts of the treaty. ***This mitigation money was not part of the negotiated multi-party treaty. It was a separate agreement between Alaska and the U.S. federal government, offered fundamentally as an incentive to Alaska to agree to the treaty.***

Under the terms of the treaty, Alaska hatchery fish caught after 1985 were not to be counted as part of the negotiated quota of allowable catch, and could be taken in addition to that quota. ***While everyone involved seemed to understand that the federal mitigation money was intended to replace what the Southeast Alaska fisheries groups had lost in the treaty settlement, the specific purpose of the money was not clearly spelled out at the time of the agreement. This lack of clarity and documentation has caused considerable confusion and controversy over the years.*** Initially many fishermen and the Alaska Department of Fish and Game believed that the money was to go towards an annual production goal of 100,000 chinook for the trollers, 1,000,000 chum for the seiners, and 20,000 to 40,000 sockeye for the gillnetters. Although the state appears to have honored the general purpose of salmon enhancement with the mitigation funds, it has not spent the funds in accordance with the most widely-held understanding of the intent for those funds.

The governments of Washington and Oregon have not allocated any funds specifically for enhancement projects related to this treaty. British Columbia instigated a treaty-related enhancement project on the Fraser River, but has since run out of funds to continue it.

A computer model was developed to calculate the allowable catch of each of the parties to the treaty, and to update that quota annually. Information about hatchery-bred fish indicates the health and numbers of the natural stocks for the computer model.

Alaska fishermen agreed to the Pacific Salmon Treaty, despite the sacrifices it required in their allowable catch levels, because of guarantees that increased hatchery efforts and production would result in increases in these allowable catches. For reasons which may have included misunderstandings of original intentions, a lack of clear binding language in the treaty, or ineffectual negotiating at annual sessions to update agreements and re-negotiate treaty annexes, many fishermen are dissatisfied with what the treaty has accomplished. Hatchery efforts funded with mitigation funds have indeed produced salmon, but fishermen, particularly trollers, do not believe they have received the benefits they were promised from that production.

While fishermen may not have seen the specific benefits they had hoped for in the form of increased allowable catches, the state hatchery program has received more funding than it would have had without mitigation funds, and the Alaska Department of Fish and Game has been able to use mitigation money to supplement their budget for projects and personnel which are related directly or indirectly to the goals of the treaty.

Yukon River Treaty

Salmon restoration and enhancement have been discussed as part of the United States/Canada Yukon River salmon negotiations since 1985. The goal of the United States in these talks has been to ensure the long-term health of salmon stocks and assure consistency in harvest for both countries of the Yukon River system.

The U.S. proposal, agreed to by the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Yukon River Drainage Fisheries Association, includes:

- Restoration projects to increase production of transboundary stocks that do not respond to harvest management.

- Fisheries enhancement projects where appropriate, consistent with state genetics and disease policies.

- Planning strategies to allocate and manage restored stocks before the program starts.

- Operational plans for enhancement projects, with protection of wild stock genetic diversity as the paramount concern.

The FRED Division has developed a Yukon Fisheries Enhancement Initiative with its key components being overall design and planning work, expansion of the Clear Hatchery near Nenana, Alaska, and rehabilitation of natural salmon production. The cost of this initiative is estimated to be more than $13 million.

Fishermen along the Yukon are primarily interested in bringing natural stocks back to historic levels. Rehabilitation projects and protection of wild stocks are their top priorities.

Some biologists believe that supplemental hatchery production on the Yukon River will only further complicate mixed stock fisheries management, and risk the reduction or elimination of small wild stocks. They are also concerned about the risks of genetic dilution of natural stocks, reduced stock fitness, and disease.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Evaluation of the effectiveness of enhancement as an international treaty component.
- Requirement of a comprehensive feasibility and benefit-cost analysis of enhancement in treaty proposals prior to treaty agreements. Because state agency budgets tend to "benefit" from enhancement agreements, consider contracting these reviews to disinterested third parties.
- Development of an auditing mechanism to determine if enhancement benefits are realized by fishermen impacted by treaty agreements.

C. ENVIRONMENTAL REGULATIONS RELATED TO ENHANCEMENT

There are a number of environmental considerations involved in the siting, construction, and operation of hatcheries. In addition to the biological and genetics matters associated with the fish and eggs themselves, other environmental protection issues include the siting of hatcheries, their water usage requirements, the effluent they produce, and the disposal of fish carcasses (of broodstock or fish which are excess or diseased).

While Alaska law does not contain many environmental statutes and regulations which are specific to hatcheries, it does have a number of general provisions regarding protection of the environment which come into play during the planning, development, and operation of hatcheries. These include the Anadromous Fish Act which controls and requires approval for any construction projects or other action which might affect "rivers, lakes or streams or parts of them that are important for the spawning, rearing or migration of anadromous fish"; the Fishways Act which requires the construction of a fishway or hatchery construction if a dam or other obstruction will impact the passage of fish (see section on environmental mitigation); plus many laws and regulations about water quality and pollution, protection of genetic purity of fish stocks (see chapter on biology and genetics), fish health inspections (AS 16.05.868), and siting of hatcheries.

A significant environmental protection issue associated with hatcheries is the discharge of waste into public waters. The procedures and permits required of hatchery operators in this regard have been confusing and in a state of flux for several years, but now seem to be headed for some resolution and streamlining. Part of the confusion stems from the fact that both the Federal Environmental Protection Agency (EPA) and the Alaska Department of Environmental Conservation (DEC) have some jurisdiction in this matter.

It appears that both EPA and DEC have been fairly lenient about requiring the various waste disposal permits that have technically been required. Even so, there have been very few complaints or problems regarding hatchery impacts on water. Hatcheries do discharge effluent which may contain organic fish waste, as well as some disinfectants or other chemicals used to prevent or control disease, but generally they discharge only very small amounts of pollutants. ***However, recent developments necessitating the disposal of large numbers of fish carcasses have raised the subject of waste disposal monitoring.*** These developments include 1) a joint decision by the Federal Food and Drug Administration and the Alaska DEC in 1990 that the carcasses of hatchery broodstock (mature fish used for the taking of eggs and milt) should no longer be sold for canning for human consumption, and 2) the recent huge returns of fish, particularly in Prince William Sound, which have resulted in the inability of hatcheries to sell large numbers of their "cost-recovery fish." Both of these developments demonstrated the need to establish procedures for hatcheries to dispose of large numbers of fish carcasses.

The federal Clean Water Act prohibits the point source discharge of pollutants by any person into the waters of the United States, except in compliance with the terms and conditions of a National Pollutant Discharge Elimination System (NPDES) permit issued by EPA. ***Under federal regulations, discharges of concentrated aquatic animal production facilities require NPDES permits.*** The regulations identify the annual level of production and feeding of a facility to require an NPDES permit, but also leaves to the EPA the discretion to require the permit of any facility it deems to be a significant contributor of pollutants.

In a January 1991 letter to all hatchery operators in Alaska, the EPA explained these requirements and noted that even if the regular operations of a hatchery did not fall under the NPDES permit guidelines, a permit would be required if the operator planned to dispose of fish carcasses in the water. It further explained that fish processors who dispose of greater than 1000 pounds of waste per day may be covered by the "Authorization to Discharge Under the National Pollutant Discharge Elimination System for Alaska Seafood Processors" general permit (the GP), and that for the purposes of carcass disposal, the EPA was willing to cover hatcheries under the same GP. The letter explained that this "greatly simplifies the administrative process and reduces the time frame in which a NPDES permit is obtained." The letter ended by asking that hatchery operators notify the EPA of their plans for fish waste disposal prior to the 1991 season.

In April 1991, the Anchorage EPA office sent another letter to all hatchery operators stating that many of the responses they had received to the January letter had raised a number of issues to be considered. Since resolving these issues is likely to take some time, the EPA established an interim policy to allow the hatcheries to operate and to provide for environmental protection in the interim period. The letter goes on to lay out three conditions under which the disposal of whole fish carcasses would be permissible. The criteria include 1) the depth of water where discharge may occur, 2) a requirement of pre-approval of the discharge site by EPA, and 3) a requirement that the skipper of the discharge vessel maintain records of each discharge occurrence, its location, and the date.

Alaska is currently operating under the interim criteria spelled out in the EPA's April 1991 letter. Many hatcheries, particularly state-run hatcheries, have submitted their applications for the NPDES permits to EPA. However, the EPA considers these state hatcheries to be minor dischargers and has agreed to turn over to the state the authority for permitting and monitoring of their waste discharge. EPA has forwarded copies to DEC of all the NPDES permit applications they have received from hatchery operators, and has asked that the state implement a hatchery waste permitting process.

Under current state law, hatchery effluent is covered under the DEC waste disposal permit statute (AS 46.03.100). DEC reports that few hatcheries apply for this permit but DEC has been comfortable with the situation, and has made permitting hatcheries a low priority, since hatcheries generally handle effluent in a manner that maintains acceptable water quality standards.

DEC has drafted a "General Waste Disposal Permit for Fish Hatchery Discharges," to be issued to hatcheries to fulfill the state waste permit requirement. Once the state has officially adopted this permit, hatchery operators will obtain waste permits only from DEC under the operating agreement between DEC and EPA. This state permit would in effect fulfill both state and federal waste permit requirements. This centralization and consolidation should simplify the permitting and reporting processes for hatchery operators, ensure more compliance, and improve uniformity in the monitoring and information available.

The state's draft permit contains a provision stating that the permit is effective until a specified date, "unless superseded before that time by a state certified EPA permit." This statement is included in order to provide for any potential situation in which EPA might require an NPDES permit, which would then supersede the state permit. The draft permit contains specific language regarding discharges, carcass disposal, drugs, chemicals and medications, operational, monitoring and reporting requirements, and so on. It lacks specific language to address disposal of diseased fish or eggs but other general provisions in the permit, or language in the hatchery operational permits from ADF&G may sufficiently provide for that circumstance.

Despite the lack of clear regulations and enforcement, and the confusion over federal and state requirements, there have been very few problems reported regarding such things as hatchery waste disposal in Alaska. Even during the situation in Prince William Sound during the 1991 season when processors would not buy many of the hatchery fish that later had to be dumped, both DEC and EPA report that their agencies worked very closely with the hatcheries to devise and carry out plans for large-scale carcass disposals, and things went quite smoothly. The Alaska Departments of Fish and Game and Environmental Conservation, and the federal Environmental Protection Agency, generally believe that for this aspect of environmental protection, current laws are adequate.

Other environmental issues related to hatcheries are covered in this report in the chapters on Biology and Genetics, Planning and Permitting, and Environmental Mitigation. The topics covered in those chapters appear to raise more serious and complex environmental concerns and questions, and need more extensive review, than the more direct environmental protection regulations discussed here.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Encouraging DEC and EPA to coordinate waste disposal permitting requirements to the extent possible.

- Ensuring that adequate direction is provided in regulation regarding the disposal of any diseased hatchery fish.

D. USE OF ENHANCEMENT AS TOOL FOR ECONOMIC DEVELOPMENT

The state's financial support of hatchery production and other enhancement efforts has focused primarily on Southeast Alaska, Prince William Sound, Cook Inlet, and Kodiak. However, fisheries enhancement is increasingly being viewed in other rural areas of the state as a tool for local economic development. Potential benefits from enhancement activities include the increased number of jobs, the potential for attracting processors or other value-added businesses to the region, as well as increased harvest for fishermen.

In some cases, the regions interested in enhancement for economic development have small, localized commercial fisheries based on local stocks of fish which in many cases are depleted, and which local residents would like to see replenished. In other areas of the state, residents are interested in the potential of creating entirely new fisheries. For many rural areas of the state, fisheries development represents the most viable -- and in many cases, perhaps the only -- opportunity for economic development.

Some of the projects being discussed and planned include:

- ***Sikusuilaq Springs Hatchery***. Residents of Kotzebue Sound are meeting with a planning core group that includes ADF&G, the National Park Service, and the Northwest Arctic Borough to develop increased production proposals as part of a basic management plan for this small state hatchery located on the Noatak River. A regional aquaculture association will probably be established in 1992, and a comprehensive salmon plan for the region should be completed in 1993.

- ***Yukon Enhancement Initiative.*** Residents of the Yukon River area are organizing an aquaculture association and seeking legislative funding so that regional enhancement planning can be reactivated and expanded. A draft comprehensive salmon plan could be completed by early 1994. Enhancement efforts are also being considered as part of the U.S./Canada Yukon River treaty negotiations.

- ***Western Alaska.*** Feasibility studies are underway for potential fisheries enhancement projects in the Nelson Island/Chevak area. Local villages and the Bering Sea Fishermen's Association are contributing to the effort, with additional funding requested from the Bureau of Indian Affairs and the National Coastal Resources Research and Development Institute. Although there are no natural runs currently, fishermen in this region are interested in developing salmon returns in streams that are ice-free year round.

- ***Norton Sound Economic Development Initiative***. Under this proposal, developed in February 1991, FRED Division is providing technical support in developing a fisheries enhancement program at Elim, including stream rehabilitation and a possible hatchery.

- ***Port Graham Salmon Development Project***. The goal of this pink salmon development project is to create a local village economy based on high quality value-added salmon products. The goal of the hatchery is to produce fish for the processing plant.

- ***Kake Nonprofit Fisheries Corporation***. This southeast Alaska community proposes to expand its Gunnuk Creek Hatchery with the express goal of contributing to the economic development of the village. Kake has historically been a fishing village, but in recent years saw logging replace fishing as the major form of employment in the community. Logging is now on the decline, and the village wishes to expand its fishing industry.

It should be noted that these enhancement proposals are subject to the same concerns and conflicts generated by enhancement projects elsewhere in the state. The continued interest in enhancement and in hatcheries however, should be a prime reason for addressing the issues highlighted in other chapters.

OPTIONS FOR POSSIBLE CONSIDERATION:

•Evaluation of how much weight to give the need for local economic development when considering a new hatchery permit application.

E. IMPORTANCE OF ENHANCEMENT TO SPORT FISHERIES

While the Senate Special Committee on Domestic and International Commercial Fisheries initiated the Legislative Review of Alaska's Fisheries Enhancement Program to evaluate the contribution of the program to commercial salmon fisheries, the role of the program in sport fisheries warrants attention. This section summarizes information provided by a FRED Division report attached to this chapter.

Many projects in the statewide enhancement program produce fish, primarily chinook, coho, pink, sockeye, and chum salmon, steelhead, rainbow trout, grayling, and Arctic char, that are highly valued by sports fishermen. Fish targeted for sport fisheries are released in over 350 locations around the state. Many of the projects operated by the FRED Division are entirely dedicated to improving recreational fishing opportunities.

Sport fishing has been growing in Alaska as evidenced by the increase in the number of licensed anglers from 1977 (200,000 total license sales) to 1990 (425,000 total license sales). This dramatic increase in sport fishing participation can be attributed to many factors, including changes in population, real per capita income of residents and non-resident visitors, and the opportunities for quality sport fishing experiences. A major component of a high quality fishing experience, especially for resident anglers, is the probability of catching a fish during the fishing experience (called the harvest per angler day). According to ADF&G, the economic value of fishing experiences are directly related to higher harvests per angler day. The statewide enhancement program has been a key factor in maintaining and augmenting these harvests despite increasing fishing effort.

The statewide salmon enhancement program has grown to the point of supporting a significant portion of total sport and commercial fishing harvests. For example, total 1990 recreational harvests of salmon, trout, grayling, Arctic char, and steelhead was approximately 1.3 million fish. The enhancement program is estimated to have contributed 28 percent of the harvest. State facilities provided 73 percent of the enhanced harvest while PNPs provided 27 percent.

According to recent studies completed by the ADF&G, sport fishing provides significant economic benefits in Alaska.

OPTIONS FOR POSSIBLE CONSIDERATION:

•If the Legislature initiates an on-going enhancement program review similar to Canada's, include sport as well as commercial fishing aspects of the program in order to achieve a more comprehensive performance report.

•Increasing the sport fish license fees to pay for a larger portion of the enhancement projects that benefit recreational fisheries.

- Encouraging Congress to increase Dingle-Johnson funds provided to Alaska to support increasing sport fishery enhancement and rehabilitation efforts.

F. CONTRIBUTION TO SUBSISTENCE FISHERIES

In addition to commercial and sport fisheries, there is increasing demand for the state's enhancement program to provide fish for subsistence and personal use fisheries.

Sikusuilaq Hatchery on the Noatak River provides a substantial number of chum salmon for subsistence gillnets in Kotzebue Sound and on the Noatak. Subsistence users in southern Southeast harvested 5,000 sockeye salmon produced from the McDonald Lake fertilization project. Production from the Klawock Hatchery, located on Prince of Wales Island, is extensively used by subsistence fishermen.

OPTIONS FOR POSSIBLE CONSIDERATION:

- If the Legislature initiates an on-going enhancement program review similar to Canada's, include subsistence and personal use as well as commercial and sport fishing aspects of the program in order to achieve a more comprehensive performance report.

G. ENHANCEMENT OF OTHER SPECIES

In addition to its work on such sport fish species as grayling, rainbow trout, and arctic char, FRED Division is also exploring king crab rehabilitation in a cooperative effort with Kodiak fishermen and the Kodiak Island Borough. Additional funding is being requested from the Alaska Science and Technology Foundation in order to examine shellfish rehabilitation projects in other countries and states.

Currently, research and production of non-salmon species is done almost entirely by the FRED Division. If private entities became interested in taking on such efforts, statutory changes would be required since the entire PNP program is based on salmon production.

OPTIONS FOR POSSIBLE CONSIDERATION:

- Amending statutes to allow the private sector to enhance non-salmon species.

- Taking action to encourage the production of non-salmon species.

Senate Resources 02.21.24 note:
Hillstrand Attachment #2

Sustainable Salmon Fisheries Policy for the State of Alaska

The Alaska Department of Fish and Game
and the Board of Fisheries

June 22, 2001

5 AAC 39.222. POLICY FOR THE MANAGEMENT OF SUSTAINABLE SALMON FISHERIES. (a) The Board of Fisheries (board) and Department of Fish and Game (department) recognize that

(1) while, in the aggregate, Alaska's salmon fisheries are healthy and sustainable largely because of abundant pristine habitat and the application of sound, precautionary, conservation management practices, there is a need for a comprehensive policy for the regulation and management of sustainable salmon fisheries;

(2) in formulating fishery management plans designed to achieve maximum or optimum salmon production, the board and department must consider factors including environmental change, habitat loss or degradation, data uncertainty, limited funding for research and management programs, existing harvest patterns, and new fisheries or expanding fisheries;

(3) to effectively assure sustained yield and habitat protection for wild salmon stocks, fishery management plans and programs require specific guiding principles and criteria, and the framework for their application contained in this policy.

(b) The goal of the policy under this section is to ensure conservation of salmon and salmon's required marine and aquatic habitats, protection of customary and traditional subsistence uses and other uses, and the sustained economic health of Alaska's fishing communities.

(c) Management of salmon fisheries by the state should be based on the following principles and criteria:

(1) wild salmon stocks and the salmon's habitats should be maintained at levels of resource productivity that assure sustained yields as follows:

(A) salmon spawning, rearing, and migratory habitats should be protected as follows:

(i) salmon habitats should not be perturbed beyond natural boundaries of variation;

(ii) scientific assessments of possible adverse ecological effects of proposed habitat alterations and the impacts of the alterations on salmon populations should be conducted before approval of a proposal;

(iii) adverse environmental impacts on wild salmon stocks and the salmon's habitats should be assessed;

(iv) all essential salmon habitat in marine, estuarine, and freshwater ecosystems and access of salmon to these habitats should be protected; essential habitats include spawning and incubation areas, freshwater rearing areas, estuarine and nearshore rearing areas, offshore rearing areas, and migratory pathways;

(v) salmon habitat in fresh water should be protected on a watershed basis, including appropriate management of riparian zones, water quality, and water quantity;

(B) salmon stocks should be protected within spawning, incubating, rearing, and migratory habitats;

(C) degraded salmon productivity resulting from habitat loss should be assessed, considered, and controlled by affected user groups, regulatory agencies, and boards when making conservation and allocation decisions;

(D) effects and interactions of introduced or enhanced salmon stocks on wild salmon stocks should be assessed; wild salmon stocks and fisheries on those stocks should be protected from adverse impacts from artificial propagation and enhancement efforts;

(E) degraded salmon spawning, incubating, rearing, and migratory habitats should be restored to natural levels of productivity where known and desirable;

(F) ongoing monitoring should be conducted to determine the current status of habitat and the effectiveness of restoration activities;

(G) depleted salmon stocks should be allowed to recover or, where appropriate, should be actively restored; diversity should be maintained to the maximum extent possible, at the genetic, population, species, and ecosystem levels;

(2) salmon fisheries shall be managed to allow escapements within ranges necessary to conserve and sustain potential salmon production and maintain normal ecosystem functioning as follows:

(A) salmon spawning escapements should be assessed both temporally and geographically; escapement monitoring programs should be appropriate to the scale, intensity, and importance of each salmon stock's use;

(B) salmon escapement goals, whether sustainable escapement goals, biological escapement goals, optimal escapement goals, or inriver run goals, should be established in a manner consistent with sustained yield; unless otherwise directed, the department will manage Alaska's salmon fisheries, to the extent possible, for maximum sustained yield;

(C) salmon escapement goal ranges should allow for uncertainty associated with measurement techniques, observed variability in the salmon stock measured, changes in climatic and oceanographic conditions, and varying abundance within related populations of the salmon stock measured;

(D) salmon escapement should be managed in a manner to maintain genetic and phenotypic characteristics of the stock by assuring appropriate geographic and temporal distribution of spawners as well as consideration of size range, sex ratio, and other population attributes;

(E) impacts of fishing, including incidental mortality and other human-induced mortality, should be assessed and considered in harvest management decisions;

(F) salmon escapement and harvest management decisions should be made in a manner that protects non-target salmon stocks or species;

(G) the role of salmon in ecosystem functioning should be evaluated and considered in harvest management decisions and setting of salmon escapement goals;

(H) salmon abundance trends should be monitored and considered in harvest management decisions;

(3) effective management systems should be established and applied to regulate human activities that affect salmon as follows:

(A) salmon management objectives should be appropriate to the scale and intensity of various uses and the biological capacities of target salmon stocks;

(B) management objectives should be established in harvest management plans, strategies, guiding principles, and policies, such as for mixed stock fishery harvests, fish disease, genetics, and hatchery production, that are subject to periodic review;

(C) when wild salmon stocks are fully allocated, new fisheries or expanding fisheries should be restricted, unless provided for by management plans or by application of the board's allocation criteria;

(D) management agencies should have clear authority in statute and regulation to

(i) control all sources of fishing mortality on salmon;

(ii) protect salmon habitats and control non-fishing sources of mortality;

(E) management programs should be effective in

(i) controlling human-induced sources of fishing mortality and should incorporate procedures to assure effective monitoring, compliance, control, and enforcement;

(ii) protecting salmon habitats and controlling collateral mortality and should incorporate procedures to assure effective monitoring, compliance, control, and enforcement;

(F) fisheries management implementation and outcomes should be consistent with regulations, regulations should be consistent with statutes, and effectively carry out the purpose of this section;

(G) the board will recommend to the commissioner the development of effective joint research, assessment, and management arrangements with appropriate management agencies and bodies for salmon stocks that cross state, federal, or international jurisdictional boundaries; the board will recommend the coordination of appropriate procedures for effective monitoring, compliance, control, and enforcement with those of other agencies, states, or nations;

(H) the board will work, within the limits of its authority, to assure that

(i) management activities are accomplished in a timely and responsive manner to implement objectives, based on the best available scientific information;

(ii) effective mechanisms for the collection and dissemination of information and data necessary to carry out management activities are developed, maintained, and utilized;

(iii) management programs and decision-making procedures are able to clearly distinguish, and effectively deal with, biological and allocation issues;

(I) the board will recommend to the commissioner and legislature that adequate staff and budget for research, management, and enforcement activities be available to fully implement sustainable salmon fisheries principles;

(J) proposals for salmon fisheries development or expansion and artificial propagation and enhancement should include assessments required for sustainable management of existing salmon fisheries and wild salmon stocks;

(K) plans and proposals for development or expansion of salmon fisheries and enhancement programs should effectively document resource assessments, potential impacts, and other information needed to assure sustainable management of wild salmon stocks;

(L) the board will work with the commissioner and other agencies to develop effective processes for controlling excess fishing capacity;

(M) procedures should be implemented to regularly evaluate the effectiveness of fishery management and habitat protection actions in sustaining salmon populations, fisheries, and habitat, and to resolve associated problems or deficiencies;

(N) conservation and management decisions for salmon fisheries should take into account the best available information on biological, environmental, economic, social, and resource use factors;

(O) research and data collection should be undertaken to improve scientific and technical knowledge of salmon fisheries, including ecosystem interactions, status of salmon populations, and the condition of salmon habitats;

(P) the best available scientific information on the status of salmon populations and the condition of the salmon's habitats should be routinely updated and subject to peer review;

(4) public support and involvement for sustained use and protection of salmon resources should be sought and encouraged as follows:

(A) effective mechanisms for dispute resolution should be developed and used;

(B) pertinent information and decisions should be effectively disseminated to all interested parties in a timely manner;

(C) the board’s regulatory management and allocation decisions will be made in an open process with public involvement;

(D) an understanding of the proportion of mortality inflicted on each salmon stock by each user group, should be promoted, and the burden of conservation should be allocated across user groups in a manner consistent with applicable state and federal statutes, including AS 16.05.251(e) and AS 16.05.258; in the absence of a regulatory management plan that otherwise allocates or restricts harvests, and when it is necessary to restrict fisheries on salmon stocks where there are known conservation problems, the burden of conservation shall be shared among all fisheries in close proportion to each fisheries' respective use, consistent with state and federal law;

(E) the board will work with the commissioner and other agencies as necessary to assure that adequately funded public information and education programs provide timely materials on salmon conservation, including habitat requirements, threats to salmon habitat, the value of salmon and habitat to the public and ecosystem (fish and wildlife), natural variability and population dynamics, the status of salmon stocks and fisheries, and the regulatory process;

(5) in the face of uncertainty, salmon stocks, fisheries, artificial propagation, and essential habitats shall be managed conservatively as follows:

(A) a precautionary approach, involving the application of prudent foresight that takes into account the uncertainties in salmon fisheries and habitat management, the biological, social, cultural, and economic risks, and the need to take action with incomplete knowledge, should be applied to the regulation and control of harvest and other human-induced sources of salmon mortality; a precautionary approach requires

(i) consideration of the needs of future generations and avoidance of potentially irreversible changes;

(ii) prior identification of undesirable outcomes and of measures that will avoid undesirable outcomes or correct them promptly;

(iii) initiation of any necessary corrective measure without delay and prompt achievement of the measure's purpose, on a time scale not exceeding five years, which is approximately the generation time of most salmon species;

(iv) that where the impact of resource use is uncertain, but likely presents a measurable risk to sustained yield, priority should be given to conserving the productive capacity of the resource;

(v) appropriate placement of the burden of proof, of adherence to the requirements of this subparagraph, on those plans or ongoing activities that pose a risk or hazard to salmon habitat or production;

(B) a precautionary approach should be applied to the regulation of activities that affect essential salmon habitat.

(d) The principles and criteria for sustainable salmon fisheries shall be applied, by the department and the board using the best available information, as follows:

(1) at regular meetings of the board, the department will, to the extent practicable, provide the board with reports on the status of salmon stocks and salmon fisheries under consideration for regulatory changes, which should include

(A) a stock-by-stock assessment of the extent to which the management of salmon stocks and fisheries is consistent with the principles and criteria contained in the policy under this section;

(B) descriptions of habitat status and any habitat concerns;

(C) identification of healthy salmon stocks and sustainable salmon fisheries;

(D) identification of any existing salmon escapement goals, or management actions needed to achieve these goals, that may have allocative consequences such as the

(i) identification of a new fishery or expanding fishery;

(ii) identification of any salmon stocks, or populations within stocks, that present a concern related to yield, management, or conservation; and

(iii) description of management and research options to address salmon stock or habitat concerns;

(2) in response to the department's salmon stock status reports, reports from other resource agencies, and public input, the board will review the management plan, or consider developing a management plan, for each affected salmon fishery or stock; management plans will be based on the principles and criteria contained in this policy and will

(A) contain goals and measurable and implementable objectives that are reviewed on a regular basis and utilize the best available scientific information;

(B) minimize the adverse effects on salmon habitat caused by fishing;

(C) protect, restore, and promote the long-term health and sustainability of the salmon fishery and habitat;

(D) prevent overfishing; and

(E) provide conservation and management measures that are necessary and appropriate to promote maximum or optimum sustained yield of the fishery resource;

(3) in the course of review of the salmon stock status reports and management plans described in (1) and (2) of this subsection, the board, in consultation with the department, will determine if any new fisheries or expanding fisheries, stock yield concerns, stock management concerns, or stock conservation concerns exist; if so, the board will, as appropriate, amend or develop salmon fishery management plans to address these concerns; the extent of regulatory action, if any, should be commensurate with the level of concerns and range from milder to stronger as concerns range from new and expanding salmon fisheries through yield concerns, management concerns, and conservation concerns;

(4) in association with the appropriate management plan, the department and the board will, as appropriate, collaborate in the development and periodic review of an action plan for any new or expanding salmon fisheries, or stocks of concern; action plans should contain goals, measurable and implementable objectives, and provisions, including

(A) measures required to restore and protect salmon habitat, including necessary coordination with other agencies and organizations;

(B) identification of salmon stock or population rebuilding goals and objectives;

(C) fishery management actions needed to achieve rebuilding goals and objectives, in proportion to each fishery's use of, and hazards posed to, a salmon stock;

(D) descriptions of new or expanding salmon fisheries, management concern, yield concern, or conservation concern; and

(E) performance measures appropriate for monitoring and gauging the effectiveness of the action plan that are derived from the principles and criteria contained in this policy;

(5) each action plan will include a research plan as necessary to provide information to address concerns; research needs and priorities will be evaluated periodically, based on the effectiveness of the monitoring described in (4) of this subsection;

(6) where actions needed to regulate human activities that affect salmon and salmon's habitat that are outside the authority of the department or the board, the department or board shall correspond with the relevant authority, including the governor, relevant boards and

commissions, commissioners, and chairs of appropriate legislative committees, to describe the issue and recommend appropriate action.

(e) Nothing in the policy under this section is intended to expand, reduce, or be inconsistent with, the statutory regulatory authority of the board, the department, or other state agencies with regulatory authority that impacts the fishery resources of the state.

(f) In this section, and in implementing this policy,

(1) "allocation" means the granting of specific harvest privileges, usually by regulation, among or between various user groups; "allocation" includes quotas, time periods, area restrictions, percentage sharing of stocks, and other management measures providing or limiting harvest opportunity;

(2) "allocation criteria" means the factors set out in AS 16.05.251(e) considered by the board as appropriate to particular allocation decisions under 5 AAC 39.205, 5 AAC 75.017, and 5 AAC 77.007;

(3) "biological escapement goal" or "(BEG)" means the escapement that provides the greatest potential for maximum sustained yield; BEG will be the primary management objective for the escapement unless an optimal escapement or inriver run goal has been adopted; BEG will be developed from the best available biological information, and should be scientifically defensible on the basis of available biological information; BEG will be determined by the department and will be expressed as a range based on factors such as salmon stock productivity and data uncertainty; the department will seek to maintain evenly distributed salmon escapements within the bounds of a BEG;

(4) "burden of conservation" means the restrictions imposed by the board or department upon various users in order to achieve escapement, rebuild, or in some other way conserve a specific salmon stock or group of stocks; this burden, in the absence of a salmon fishery management plan, will be generally applied to users in close proportion to the users' respective harvest of the salmon stock;

(5) "chronic inability" means the continuing or anticipated inability to meet escapement thresholds over a four to five year period, which is approximately equivalent to the generation time of most salmon species;

(6) "conservation concern" means concern arising from a chronic inability, despite the use of specific management measures, to maintain escapements for a stock above a sustained escapement threshold (SET); a conservation concern is more severe than a management concern;

(7) "depleted salmon stock" means a salmon stock for which there is a conservation concern;

(8) "diversity", in a biological context, means the range of variation exhibited within any level of organization, such as among genotypes within a salmon population, among populations within a salmon stock, among salmon stocks within a species, among salmon species within a community, or among communities within an ecosystem;

(9) "enhanced salmon stock" means a stock of salmon that is undergoing specific manipulation, such as hatchery augmentation or lake fertilization, to enhance its productivity above the level that would naturally occur; "enhanced salmon stock" includes an introduced stock, where no wild salmon stock had occurred before, or a wild salmon stock undergoing manipulation, but does not include a salmon stock undergoing rehabilitation, which is intended to restore a salmon stock's productivity to a higher natural level;

(10) "escapement" means the annual estimated size of the spawning salmon stock; quality of the escapement may be determined not only by numbers of spawners, but also by factors such as sex ratio, age composition, temporal entry into the system, and spatial distribution within the salmon spawning habitat;

(11) "expanding fishery" means a salmon fishery in which effective harvesting effort has recently increased significantly beyond historical levels and where the increase has not resulted from natural fluctuations in salmon abundance;

(12) "expected yields" mean levels at or near the lower range of recent historic harvests if they are deemed sustainable;

(13) "genetic" means those characteristics (genotypic) of an individual or group of salmon that are expressed genetically, such as allele frequencies or other genetic markers;

(14) "habitat concern" means the degradation of salmon habitat that results in, or can be anticipated to result in, impacts leading to yield, management, or conservation concerns;

(15) "harvestable surplus" means the number of salmon from a stock's annual run that is surplus to escapement needs and can reasonably be made available for harvest;

(16) "healthy salmon stock" means a stock of salmon that has annual runs typically of a size to meet escapement goals and a potential harvestable surplus to support optimum or maximum sustained yield;

(17) "incidental harvest" means the harvest of fish, or other species, that is captured in addition to the target species of a fishery;

(18) "incidental mortality" means the mortality imposed on a salmon stock outside of directed fishing, and mortality caused by incidental harvests, interaction with fishing gear, habitat degradation, and other human-related activities;

(19) "inriver run goal" means a specific management objective for salmon stocks that are subject to harvest upstream of the point where escapement is estimated; the inriver run goal will be set in regulation by the board and is comprised of the SEG, BEG, or OEG, plus specific allocations to inriver fisheries;

(20) "introduced stock" means a stock of salmon that has been introduced to an area, or portion of an area, where that stock had not previously occurred; an "introduced stock" includes a salmon stock undergoing continued enhancement, or a salmon stock that is left to sustain itself with no additional manipulation;

(21) "management concern" means a concern arising from a chronic inability, despite use of specific management measures, to maintain escapements for a salmon stock within the bounds of the SEG, BEG, OEG, or other specified management objectives for the fishery; a management concern is not as severe as a conservation concern;

(22) "maximum sustained yield" or "(MSY)" means the greatest average annual yield from a salmon stock; in practice, MSY is achieved when a level of escapement is maintained within a specific range on an annual basis, regardless of annual run strength; the achievement of MSY requires a high degree of management precision and scientific information regarding the relationship between salmon escapement and subsequent return; the concept of MSY should be interpreted in a broad ecosystem context to take into account species interactions, environmental changes, an array of ecosystem goods and services, and scientific uncertainty;

(23) "mixed stock fishery" means a fishery that harvests fish from a mixture of stocks;

(24) "new fishery" means a fishery that new units of effort or expansion of existing effort toward new species, areas, or time periods, results in harvest patterns substantially different from

those in previous years, and the difference is not exclusively the result of natural fluctuations in fish abundance;

(25) "optimal escapement goal" or "(OEG)" means a specific management objective for salmon escapement that considers biological and allocative factors and may differ from the SEG or BEG; an OEG will be sustainable and may be expressed as a range with the lower bound above the level of SET, and will be adopted as a regulation by the board; the department will seek to maintain evenly distributed escapements within the bounds of the OEG;

(26) "optimum sustained yield" or "(OSY)" means an average annual yield from a salmon stock considered to be optimal in achieving a specific management objective other than maximum yield, such as achievement of a consistent level of sustained yield, protection of a less abundant or less productive salmon stock or species, enhancement of catch per unit effort in sport fishery, facilitation of a non-consumptive use, facilitation of a subsistence use, or achievement of a specific allocation;

(27) "overfishing" means a level of fishing on a salmon stock that results in a conservation or management concern;

(28) "phenotypic characteristics" means those characteristics of an individual or group of salmon that are expressed physically, such as body size and length at age;

(29) "rehabilitation" means efforts applied to a salmon stock to restore it to an otherwise natural level of productivity; "rehabilitation" does not include an enhancement, which is intended to augment production above otherwise natural levels;

(30) "return" means the total number of salmon in a stock from a single brood (spawning) year surviving to adulthood; because the ages of adult salmon (except pink salmon) returning to spawn varies, the total return from a brood year will occur over several calendar years; the total return generally includes those mature salmon from a single brood year that are harvested in fisheries plus those that compose the salmon stock's spawning escapement; "return" does not include a run, which is the number of mature salmon in a stock during a single calendar year;

(31) "run" means the total number of salmon in a stock surviving to adulthood and returning to the vicinity of the natal stream in any calendar year, composed of both the harvest of adult salmon plus the escapement; the annual run in any calendar year, except for pink salmon, is composed of several age classes of mature fish from the stock, derived from the spawning of a number of previous brood years;

(32) "salmon" means the five wild anadromous semelparous Pacific salmon species *Oncorhynchus sp*., except steelhead and cutthroat trout, native to Alaska as follows:

(A) chinook or king salmon *(O. tschawytscha*);

(B) sockeye or red salmon (*O. nerka*);

(C) coho or silver salmon (*O. kisutch*);

(D) pink or humpback salmon (*O. gorbuscha*); and

(E) chum or dog salmon (*O. keta*);

(33) " salmon population" means a locally interbreeding group of salmon that is distinguished by a distinct combination of genetic, phenotypic, life history, and habitat characteristics, comprised of an entire stock or a component portion of a stock; the smallest uniquely identifiable spawning aggregation of genetically similar salmon used for monitoring purposes;

(34) "salmon stock" means a locally interbreeding group of salmon that is distinguished by a distinct combination of genetic, phenotypic, life history, and habitat characteristics or an

aggregation of two or more interbreeding groups which occur within the same geographic area and is managed as a unit;

(35) "stock of concern" means a stock of salmon for which there is a yield, management, or conservation concern;

(36) "sustainable escapement goal" or "(SEG)" means a level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5 to 10 year period, used in situations where a BEG cannot be estimated due to the absence of a stock specific catch estimate; the SEG is the primary management objective for the escapement, unless an optimal escapement or inriver run goal has been adopted by the board, and will be developed from the best available biological information; the SEG will be determined by the department and will be stated as a range that takes into account data uncertainty; the department will seek to maintain escapements within the bounds of the SEG;

(37) "sustainable salmon fishery" means a salmon fishery that persists and obtains yields on a continuing basis; characterized by fishing activities and habitat alteration, if any, that do not cause or lead to undesirable changes in biological productivity, biological diversity, or ecosystem structure and function, from one human generation to the next;

(38) "sustained yield" means an average annual yield that results from a level of salmon escapement that can be maintained on a continuing basis; a wide range of average annual yield levels is sustainable; a wide range of annual escapement levels can produce sustained yields;

(39) "sustained escapement threshold" or "(SET)" means a threshold level of escapement, below which the ability of the salmon stock to sustain itself is jeopardized; in practice, SET can be estimated based on lower ranges of historical escapement levels, for which the salmon stock has consistently demonstrated the ability to sustain itself; the SET is lower than the lower bound of the BEG and lower than the lower bound of the SEG; the SET is established by the department in consultation with the board, as needed, for salmon stocks of management or conservation concern;

(40) "target species" or "target salmon stocks" means the main, or several major, salmon species of interest toward which a fishery directs its harvest;

(41) "yield" means the number or weight of salmon harvested in a particular year or season from a stock;

(42) "yield concern" means a concern arising from a chronic inability, despite the use of specific management measures, to maintain expected yields, or harvestable surpluses, above a stock's escapement needs; a yield concern is less severe than a management concern, which is less severe than a conservation concern;

(43) "wild salmon stock" means a stock of salmon that originates in a specific location under natural conditions; "wild salmon stock" may include an enhanced or rehabilitated stock if its productivity is augmented by supplemental means, such as lake fertilization or rehabilitative stocking; "wild salmon stock" does not include an introduced stock, except that some introduced salmon stocks may come to be considered "wild" if the stock is self-sustaining for a long period of time.

(44) "action point" means a threshold value for some quantitative indicator of stock run strength at which an explicit management action will be taken to achieve an optimal escapement goal.

Evaluating Alaska's Ocean-Ranching Salmon Hatcheries: *Biologic and Management Issues*

Environment and Natural Resources Institute
University of Alaska Anchorage

Senate Resources 02.21.24 note:
Hillstrand Attachment #3

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EXECUTIVE SUMMARY

This review of the biologic and management issues surrounding ocean-ranching hatcheries summarizes both the documented and theoretical threats that these facilities pose to Alaska's wild salmon. It focuses on North Pacific Rim hatchery production and examines the topics of genetics, straying, ecological interactions between wild and hatchery fish, fish-culture practices, biological concerns associated with managing mixed wild and hatchery stock fisheries, questions of the ocean's carrying capacity, and global climatic regime shifts together with associated management implications.

Alaska's ocean-ranching salmon hatcheries operate amidst considerable uncertainty. Perhaps the most striking feature uncovered by this review was the many gaps in the scientific data from which one could fairly draw conclusions of the effects hatcheries may or may not have on wild salmon. Alaska has been successful in augmenting salmon harvest with hatchery-produced fish, but whether or not salmon biodiversity has been adequately protected in the process is unanswered. Data necessary to evaluate interactions between hatchery and wild salmon populations have not, in most cases, been collected. Better data are needed to bring consensus among scientists and managers on how to figure uncertainties into the management equations, such as ocean carrying capacity and genetic risk to wild fish from hatchery straying.

After more than 30 years of debate about the impact of hatchery fish on the genetic diversity of wild salmon populations, there is still no definitive answer to this concern (even given the increase in the body of knowledge). While it may be easy to identify potential risks that hatcheries pose for natural populations, it is not so easy to predict whether deleterious effects have occurred or how serious the consequences may be. However, the documented high incidence of straying of hatchery fish (especially pink and chum salmon in Prince William Sound and Southeast Alaska, respectively) suggests that large-scale ocean ranching has the potential to severely disrupt the extensive population genetic structure that exists among wild salmon populations—a structure that many biologists believe correlates to adaptive traits. To date, there is insufficient data from genetic studies monitoring wild stocks proximal to hatcheries to resolve such issues. But, if such impacts are of a significant magnitude, the operations of certain hatcheries may not be in line with the State of Alaska's Sustainable Salmon Fisheries, Finfish Genetics, and Salmon Escapement Goal Policies nor with its wild-stock priority.

The need to conserve genetic information is fundamental to salmon biodiversity. Both commercial fishing and hatchery production can adversely affect genetic diversity. Alaska's Finfish Genetics Policy recommends designation of hydrologic basins or geographic areas as gene preserves—perpetual repositories of genetic information for all plant and animal species inhabiting such areas. Currently, there are no officially recognized gene preserves in Alaska specifically established for salmon. The state's Finfish Genetics Policy came about as a result of concern that the development and operation of a hatchery system could have a detrimental impact on wild salmon populations. The policy has not been revised since 1985.

Management of a mixed-stock fishery is complex. Factoring hatchery fish into this management equation only makes a hard job more difficult. It is important not to overharvest small salmon populations that may contain unique adaptive traits (and genes). Given the number of streams in Alaska (and the corresponding number of salmon stocks), coupled with the size of the Alaska Department of Fish and Game's staff and budget, conducting the monitoring required to ensure that no wild salmon stocks are being negatively impacted by overfishing or invasion of hatchery strays is nearly impossible. In Prince William Sound alone, the Department currently monitors 150 to 200 of the approximate 800 streams for escapement. In order to monitor all 800, more staff and budget would be needed. The use of thermal marking is a significant advance in technology that enables a closer and more thorough monitoring of mixed-stock fisheries and consequently better protection of wild stocks. At present, there is inadequate information to provide for reliable and timely estimates of wild-stock escapements and run sizes that are needed to direct management of the mixed-stock fisheries, especially for those that harvest chum salmon in Southeast Alaska.

Competition for resources between hatchery and wild salmon stocks has become a significant concern. Based on a review of the literature and discussions with biologists, geneticists, and fishery managers, it is widely believed that extensive ocean ranching may pose a threat to the ocean's carrying capacity and the protection of salmon biodiversity. This may be the most important issue for assessing risks to wild salmon, especially for populations with comparatively small numbers of individuals, and it may be more significant than the risk of loss or change in genetic diversity due to hatchery practices. The potential for hatchery-bred salmon to displace wild fish in the ocean, coupled with the overall lack of knowledge about complex dynamics of the North Pacific ecosystem, suggests that it would be prudent to manage the hatcheries in Alaska conservatively, especially in years of lower ocean-productivity indices.

Fisheries management currently has little data on the effects of ocean variability on marine survival of salmonids even though salmon stocks clearly respond to shifts in climate. Ongoing scientific pursuits should help pinpoint which physical and biological processes lead to changes in salmon growth and survival so that, as the ocean enters a new climate regime, we are able to predict and account for changing trends of fish growth and survival due to marine variables.

With respect to fish-culture practices, Alaska's hatcheries are among the best in North America. The main reasons for this are both fortuitous and purposeful. By concentrating on pink and chum salmon, Alaska's ocean-ranching program has avoided many of the attenuated problems (e.g. domestication and ecological) with long-term rearing species like steelhead trout and coho salmon. Given the late date at which Alaska's ocean-ranching program was established, the state was able to benefit from mistakes made elsewhere. The program started on better footing by having genetic oversight of operations through fish transport permits, hatchery siting, egg takes, broodstock development, etc. Oversight of fish diseases by the state's pathology department has been exemplary and closely follows Alaska's Fish and Shellfish Health and Disease Control Policy.

Given the biologic and management questions of ocean ranching, prioritizing research objectives can help narrow existing information gaps. The State of Alaska has an extensive permitting procedure for starting a hatchery, thorough pathology guidelines, and an adequate genetics policy. However, once operating, hatcheries do not face stringent supervision, monitoring, or evaluation. As can be seen by perusing the reports or plans currently available, it is difficult if not impossible to gauge whether hatchery programs are impacting wild stocks.

Monitoring of hatchery practices is a duty and responsibility of each of the Regional Planning Teams established by the Alaska Department of Fish and Game. Judging from the type of reports they produce (e.g., annual hatchery management plans), their primary concern is development of hatchery-production plans and evaluating the resulting contribution to fisheries. Extensive documentation exists for egg takes, incubation, rearing, and broodstock, as well as for fisheries management for hatchery returns including common property fisheries, special harvest areas, cost recovery, and marking/tagging studies. While this is useful information, it is difficult to ascertain whether the Regional

Planning Teams perform any substantive review of hatchery operations as is specified in the description of planning team duties. For instance, there is virtually no information about whether the egg take reflects the run-timing characteristics of the stock, the degree to which adequate numbers of spawners are used for hatchery broodstock, how often a stock has been used as a brood source, straying rates, or the number and final destination of fish that escape the cost-recovery harvest. Some plans have information that addresses the protection of wild stocks, however, there is almost no information on how effective any of the proposed measures have been. As to whether a site for a hatchery is appropriate (one of the public benefit criteria), there is no published documentation addressing this point.

This report concludes that industrial-scale hatchery salmon production, which releases billions of smolts into the North Pacific Ocean, could be jeopardizing Alaska's wild salmon. Additionally, there are legitimate management questions as to whether hatchery operations in Alaska are in line with current Alaska Department of Fish and Game policies, including the Sustainable Salmon Fisheries Policy.

INTRODUCTION

Today there is much concern over the status and fate of wild salmon populations. Fueling this are recently published reports by several preeminent scientists questioning the degree to which human activities have impacted the overall biodiversity of wild salmon. In response, Trout Unlimited launched its Alaska Salmonid Biodiversity Program in Alaska in January 2000. Soon thereafter, the Program published a survey of its concerns about Alaska salmon and salmon fisheries (Konigsberg 2000). One concern focused on the future management and protection of wild salmon biodiversity and specifically identified Alaska's ocean-ranching program as a potential threat to wild salmon biodiversity. To further investigate this, Trout Unlimited contracted with the University of Alaska Anchorage's Environment and Natural Resources Institute (ENRI) in October 2000 to review and summarize information on both the documented and theoretical threats associated with ocean-ranching programs to Alaska's wild salmon populations.

This report is the result of that investigation. It begins with an overview of North Pacific Rim hatchery production and then reviews specific scientific and management issues associated with hatchery production. Topics addressed include straying and the potential genetic impacts of introgression and hybridization versus the demographic effects of displacement. Data germane to the ecological interactions between wild and hatchery fish are presented, such as density-dependent competition for resources, predation, and altered behaviors of hatchery-produced salmon compared to wild salmon. Marine concerns, such as understanding the ocean's carrying capacity and predicting global climatic regime shifts, are considered as well as management implications. Finally, it provides an in-depth look at Alaska hatchery management and fish-culture practices, policies, and the biologic concerns associated with managing mixed wild and hatchery stock fisheries. This report does not address the socioeconomic issues associated with the ocean-ranching industry.

Note that the terms *stock* and *population* are used interchangeably throughout this report as are the terms *ocean ranching* and *salmon ranching*. With the exception of sockeye salmon *(Oncorhynchus nerka)* aquaculture, where juvenile sockeye are released into natural freshwater environments for rearing, the preponderance of Alaska hatcheries are located adjacent to the sea and produce pink salmon *(Oncorhynchus gorbuscha)* and chum salmon *(Oncorhynchus keta)* that are released directly into marine waters. Rather than use the terms *enhancement* and *supplementation*, which have imprecise meanings, this report simply distinguishes between hatchery-produced and wild or naturally-produced salmon.

NORTH PACIFIC RIM HATCHERY PRODUCTION

Since 1991 Canada, Japan, Russia, and the United States have annually released 5 to 6 billion hatchery-reared salmon into the Pacific Ocean (Beamish, et al. 1997; North Pacific Anadromous Fish Commission [NPAFC] 1995). A brief overview of hatchery production of the North Pacific salmon fishery by major areas of production is presented below to help establish the scale of these activities. A more detailed section covering Alaska management, regulations, and policies is presented later in this report.

BRITISH COLUMBIA, CANADA

The joint federal/provincial Salmonid Enhancement Program (SEP) of Canada was initiated in 1977 with the long-term objective of doubling the catch of Pacific salmon *(Oncorhynchus spp.)*, steelhead trout *(Oncorhynchus mykiss)*, and sea-run cutthroat trout *(Oncorhynchus clarki)* by protecting, rehabilitating, and enhancing fish stocks throughout British Columbia. Projects were designed to restore depressed stocks through improved management and employment of various restoration and enhancement techniques. The methods used have included improvement of fish habitat, removal of barriers to fish migration, construction of both in-river spawning channels and groundwater side channels for spawning habitat, placement of cover to increase rearing habitat, enrichment of streams and lakes, stabilization of stream banks, and fish culture. Fish culture plays a major role in SEP. Its annual stocking programs are intended to accelerate recovery of severely depleted wild stocks and to sustain major sport and some commercial fisheries. Fish culture methods include hatcheries, spawning and rearing channels, and instream incubation boxes (Kelly et al. 1990).

Hatcheries built under SEP provide well over 10% of the total British Columbia catch of coho salmon *(Oncorhynchus kisutch)* and chinook salmon *(Oncorhynchus tshawytscha)*. SEP fish production in 1984 was over 375 million juveniles (including the six Pacific salmon species and cutthroat trout) from all enhancement techniques. Major production in 1984 was from 32 hatcheries, four spawning channels, and two side channel improvement projects. Over one-half of fish production in 1984 came from three facilities: the Big and Little Qualicum spawning channels and hatcheries and the Babine spawning channels. The Babine facility produces over 100 million sockeye salmon juveniles annually and the Big and Little Qualicum facilities produce over 80 million juveniles, most of which are chum salmon (Kelly et al. 1990).

British Columbia currently has 38 federal hatcheries, and there are also 150 public involvement projects ranging from classroom incubators to hatcheries producing about 2 million juveniles. Peak production from SEP facilities occurred in 1990 when just over 650 million fish were released including 66 million chinook, 189 million chum, 21 million coho, 283 million sockeye, and 88 million pink salmon. Since then there has been a declining trend, with significant reductions of released juvenile chum salmon into the rivers of the Georgia Basin. Approximately 429 million fish were released in 1998; chum (154 million) and sockeye (186 million) salmon were the most numerous (R. Cook, pers. comm.). Up to 80% of the juvenile coho salmon in southern British Columbia coastal waters have been attributed to enhancement projects (Noakes et al. 2000a).

JAPAN

Japan operates the most extensive ocean-ranching program in the world both in terms of the number of hatcheries and the number of juveniles released annually. There are 150 hatcheries on Hokkaido and 165 on Honshu (Heard 1996), most of which are operated by private fisherman cooperatives.

From the mid-1980s to the mid-1990s, over 2 billion juvenile salmon were released annually from these hatcheries. Most were chum salmon, and a little over 100 million pink and 10 million masu *(Oncorhynchus masu)* salmon were released as well. In 1995 Japanese hatcheries released just over 2 billion chum, 118 million pink, and 13 million masu salmon (NPAFC 1995).

All Japanese stocks of salmon except for masu are maintained by artificial propagation. For management purposes there is basically one stock of chum salmon, which is supported by an extensive hatchery program. Any adult fish returning in excess to those needed by Japanese hatcheries are generally harvested and not allowed to spawn naturally (Moberly and Lium 1977). Thus, any possible conflict between wild and hatchery chum salmon stocks in Japan is moot as the species exists there almost solely as a result of artificial fish culture.

SOUTH KOREA

South Korea has a small hatchery program that began in 1913. Hatchery-produced chum salmon are released in 12 streams on the east coast of South Korea. Between 1970 and 1995 the number of juvenile chum salmon released annually increased from 8 thousand to 16 million (Seong 1998).

RUSSIA

The first salmon hatcheries in Russia were built by the Soviets in the 1920s at Teplovka Lake (a tributary to Amur River) and at Lake Ushkovskoye (a tributary to Kamchatka River). The Japanese also built a number of salmon hatcheries in the late 1920s in the northern part of Sakhalin Island and in the Kurile Islands that came under Russian control following World War II. A total of 25 hatcheries were in operation by 1964. Subsequently, the more inefficient hatcheries were abandoned. There are currently 22 operating in the far east of Russia: 17 on Sakhalin Island, 4 on Amur River tributaries, and 1 on a Kamchatka River tributary. The number of juveniles released from these hatcheries between 1985 and 1990 was between 600 and 700 million; about 450 million were pink salmon and 200 million were chum salmon (Dushkina 1994). In 1995, approximately 478 million hatchery fish were released; almost all were pink and chum salmon along with a few million sockeye and coho salmon (NPAFC 1995). About 500 to 550 million Pacific salmon fry are released annually; about 52% are pink and 48% are chum (Radchenko 1998).

U.S. PACIFIC NORTHWEST

Development of salmon hatcheries in the U.S. Pacific Northwest began in the late nineteenth century. Hatcheries have played an increasingly prominent role in salmon supplementation and enhancement in the region ever since. Most public hatcheries were built to mitigate for extensive losses of natural habitat due to industrial development, urbanization, and especially to damming of major river systems like the Columbia. In the Columbia River Basin alone, for example, there are now nearly 100 hatcheries producing about 200 million juveniles each year (Flagg et al. 2000).

Chinook was the first salmon species to be artificially propagated in western North America; this occurred in 1872 on the McCloud River in California. More chinook salmon have been produced from hatcheries than any other species in the Pacific Northwest. Today, the Columbia River Basin is the center of chinook hatchery production, with approximately 27% of the world's chinook salmon being cultured there (Mahnken et al. 1998). Hatchery production of chinook salmon in Washington State began in 1895 at the Kalama (a Columbia River tributary) hatchery. Production grew to about 50 million released fish by the late 1930s. By the early 1980s, more than 300 million chinook salmon were being released from Pacific Northwest hatcheries.

Coho salmon are among the most successful of hatchery-cultivated species in the Pacific Northwest.

In the 1960s advances in feed, disease prevention, and better understanding of the early life-history culture requirements of coho salmon led to improved survival of hatchery fish. Increased reliance on hatchery coho salmon led to rapid expansion of production through the 1970s. In 1981 a record 198 million hatchery coho salmon were released from Pacific Northwest hatcheries. In the following years coho salmon production in the Pacific Northwest stabilized and then began to decline. By 1995 only 72 million coho were released from Pacific Northwest hatcheries (NPAFC 1995).

In 1995 approximately 470 million fish were released from hatcheries in four Pacific Northwest states: California, Idaho, Oregon, and Washington. About 64% of the hatchery fish in this region are produced in Washington, where hatchery enhancement has been an integral part of salmon management programs since the early 1900s. By 1976 there were 52 separate salmon enhancement projects operating statewide, 39 of which were hatcheries. The total 1976 enhancement effort resulted in release of over 151 million chinook, coho, chum, and pink salmon. By 1985 this program had grown to 111 projects statewide including 70 hatcheries. The total release for 1985 was over 365 million fish; over 99% of these were chinook, coho, and chum salmon (Kelly et al. 1990). In 1995 Washington hatcheries released just over 300 million fish: 159 million chinook, 57 million coho, 59 million chum, 16 million sockeye, and 11 million steelhead. In the same year Oregon released 80 million fish, California 67 million, and Idaho 17 million; most of these fish were chinook salmon (NPAFC 1995).

ALASKA

There was a flurry of private hatchery construction in Alaska during the early 1900s (primarily in Southeast, Prince William Sound, and Kodiak Island), but it was short-lived and with little apparent success. An amendment in 1900 to the Alaska Salmon Fisheries Act required any person, company, or corporation taking salmon for commercial purposes in Alaska waters to establish a hatchery (Roppel 1982). This amendment was poorly conceived and not stringently enforced. A number of canning companies did construct hatcheries, but they were poorly sited. Water was often of poor quality and quantity, and insufficient numbers of salmon returned to provide eggs for incubation. Two major company hatcheries were built in Southeast Alaska near Ketchikan: one at Boca de Quadra and the other at Heckman Lake. The latter was eventually enlarged to a capacity of 110 million eggs and at the time was the largest in the world (Roppel 1982). By 1936 all hatcheries in Alaska had closed.

Only one attempt was made to propagate salmon in Alaska between the 1930s and 1950s. It was an experimental pink salmon hatchery operated by the U.S. Fish and Wildlife Service (FWS) at Little Port Walter on south Baranof Island in Southeast Alaska. By then a complete reversal of management philosophy had taken place since the federal government first mandated artificial propagation. A policy of regulating the fisheries replaced that of artificial propagation and remained in effect in Alaska until the 1970s.

In the mid-1970s, commercial salmon harvests in Alaska reached near historic lows (20 to 25 million fish) compared with the very high salmon harvests of the 1930s (100 to 126 million fish). To counteract declining commercial salmon harvests, the state embarked on an ambitious salmon enhancement program. By 1988 the Alaska Department of Fish and Game (ADF&G) was operating 16 hatcheries throughout Alaska, which were annually producing more than 300 million juvenile salmon (Kelly et al. 1990). There are currently 2 state hatcheries, 27 private hatcheries, and 3 federal hatcheries operating in Alaska (Figure 1). The state hatcheries primarily produce salmonid species targeted for sport fisheries. Private hatchery corporations are permitted to operate salmon hatcheries and recoup their operational costs from the harvest of adult fish. Two of the federal hatcheries are generally used for

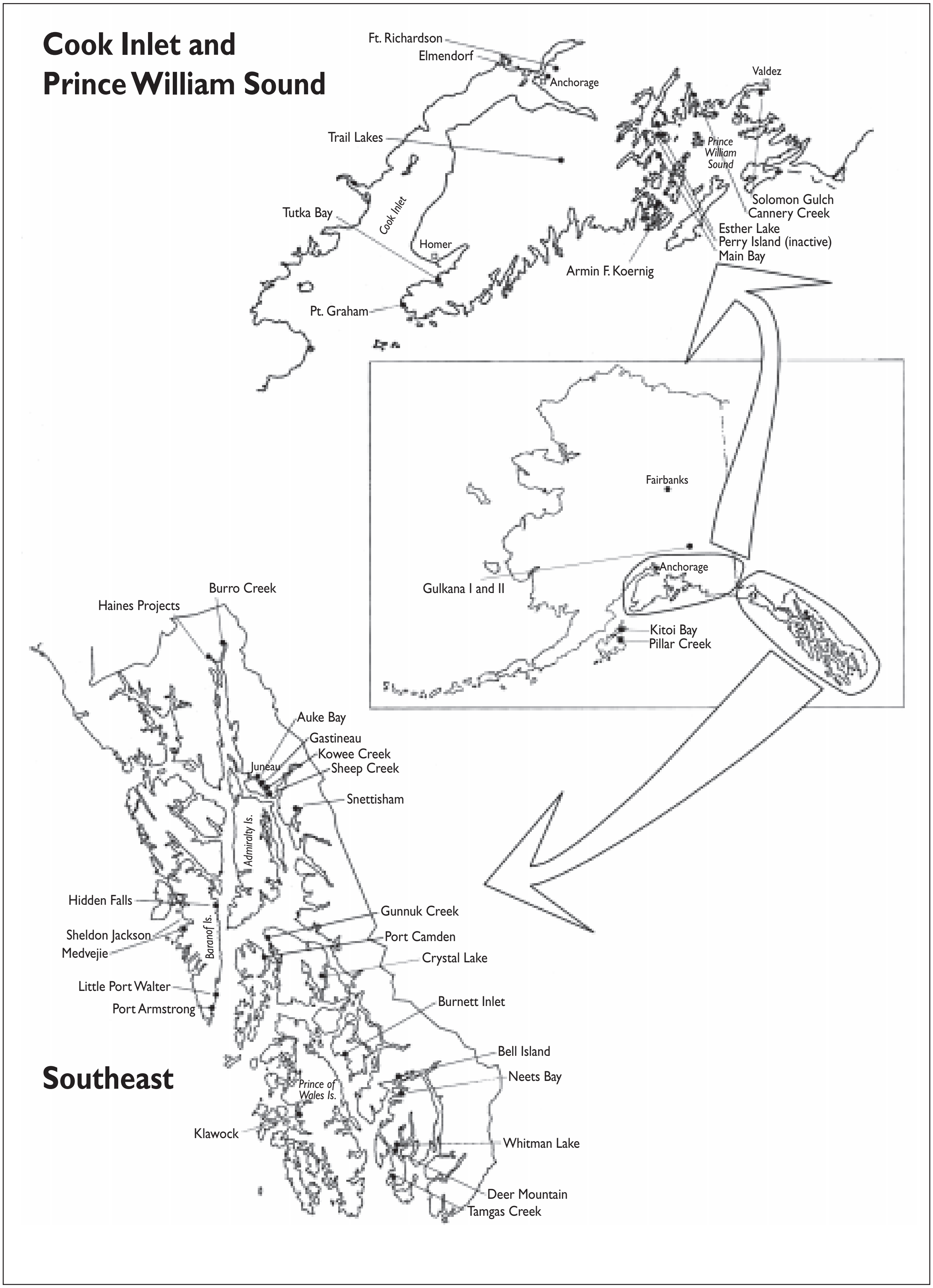

Figure 1. Hatchery locations in Alaska (McNair 2001).

research and the third is operated by the Metlakatla Indian Community with oversight by the U.S. Bureau of Indian Affairs (McNair 2001).

Pink and chum salmon make up the largest proportion of salmon produced in Alaska hatcheries and all come from private hatcheries. Prince William Sound and Southeast Alaska are the predominant regions in which hatchery production occurs. The Prince William Sound Aquaculture Corporation (PSWAC) operates the largest hatchery program in North America, releasing more than 400 million pink salmon each year. A little over 1.4 billion salmon were released from Alaska hatcheries in 2000, including nearly 600 million pinks in Prince William Sound and 385 million chums in Southeast. Production levels, in terms of egg take and releases, were at about this level throughout the 1990s (McNair 2001).

Hatchery-produced fish accounted for roughly 34% of the commercial common property harvest of salmon in 2000 (McNair 2001). Of these, 64% were chum; 42% were pink; 24% were coho; 4% were sockeye; and 19% were chinook (Table 1). Regionally, the relative hatchery contribution varied considerably from a high of nearly 80% of all salmon caught in Prince William Sound; 27% in Southeast; 10% in Cook Inlet; 32% in Kodiak; and 0% in the Chignik/Alaska Peninsula, Bristol Bay, and Arctic-Yukon-Kuskokwim areas (Table 1).

Table 1. Alaska commercial harvest of hatchery-produced fish in 2000.

Region	Percentage of Hatchery-Produced Fish in Commercial Harvest by Species					Percent of Total Harvest
	Chinook	Sockeye	Coho	Pink	Chum	
Southeast	30	16	20	1	73	27
Prince William Sound	0	34	65	82	88	80
Cook Inlet	8	15	3	2	0	10
Kodiak	0	16	40	37	26	32
Chignik/Alaska Peninsula	0	0	0	0	0	0
Bristol Bay	0	0	0	0	0	0
Arctic-Yukon-Kuskokwim	0	0	0	0	0	0
Statewide	*19*	*4*	*24*	*42*	*64*	*34*

BIOLOGIC ISSUES

Salmon hatchery operations have a long history and figure prominently in the fisheries programs of all of the states, provinces, and nations that have indigenous salmon populations. From the outset hatcheries have been surrounded by controversy, and their perceived benefits have waxed and waned periodically with changing public attitudes and with scientific advances in their operations. This section of the report focuses on the fundamental biologic issues associated with salmon hatcheries: genetics, homing/straying, ecological interactions, and limitations of the marine environment.

GENETICS

Populations of many fish species, particularly the salmonids, are characterized by complex structures of subpopulations representing historically developed population aggregates. Such aggregates share common spawning areas and times, yet maintain independent morphologic and behavioral characters and a high degree of genetic isolation. These population systems as a whole are characterized by long-term genetic stability due to reciprocal balance between dynamic factors, such as random genetic drift and migration and the stabilizing influence of natural selection (Ryman and Utter 1987). In other words, wild fish are adapted to their environment.

In general, declines in population productivity from habitat degradation and the nongenetic effects of overfishing have caused greater losses in productivity or population resilience than has genetic degradation. In the long term (e.g., over scores of generations), however, the harmful effects of accumulated genetic degradation within populations, loss of populations and the associated genetic diversity, and the accompanying hindrance of genetic adaptation to changing environmental conditions may equal or exceed the effects of habitat degradation and overfishing. The productivity of populations and their resilience to environmental change is a result of their genetic diversity (Busack and Currens 1995). Even a modest loss of adaptiveness for already degraded populations may cause extinction in the absence of rapid genetic recovery or favorable human intervention (Reisenbichler 1996). Furthermore, different salmonid populations use spawning, rearing, migratory, and oceanic resources in a variety of ways and can be expected to show a similar diversity in response to changing environmental conditions. This diversity therefore can be expected to buffer total productivity for the resource against periodic or unpredictable changes. Events of the recent past, in particular the eruption of Mount St. Helens and the strong El Niño events, remind us that, on an evolutionary time scale, sudden and drastic change is the rule rather than the exception. Loss of interpopulational diversity thus may lead to a reduction in overall productivity and a greater vulnerability to environmental change (Waples 1991).

Conservation of genetic resources and minimization of genetic risks from artificial propagation are emerging as a central fisheries management issue, and discussion about the role of genetics in fishery management has increased markedly since the 1970s. This can be seen by the numerous papers, symposia, and workshops on the topic (Allendorf and Waples 1996; Busack and Currens 1995; Campton 1995; Kelly et al. 1990; National Research Council 1996; Reisenbichler 1996; Reisenbichler and Rubin 1999; Scientific Review Team 1998; Sound Science Review Team 1999; Waples 1991, 1999).

Many lines of evidence suggest that hatchery production may adversely affect wild stocks. In the last 100 years, at least 27 species and 13 subspecies (40 taxa) of North American fish have become extinct. Among possible contributing factors that have been suggested to have led to such extinctions are effects of introduced species (27 of 40 taxa), hybridization (15 of 40 taxa), and overharvesting (6 of 40 taxa) (Williams et al. 1989). These results can be linked at various levels to hatchery operations or fish stockings, justifying widespread concern among many biologists about loss of genetic diversity. However, while it is easy to identify risks that hatcheries pose for natural populations, it is not so easy to predict whether deleterious effects will occur or, if they do, how serious the consequences will be (Waples 1999).

Stock or fish transfers among hatcheries or watersheds are well documented. This is especially true for salmon and steelhead in the Pacific Northwest where artificial gene flow and mixing of previously isolated gene pools have historically been standard practices. In the Columbia River, similar gene frequencies characterize several hatchery populations of chinook salmon (Utter et al. 1989). All hatchery summer steelhead for Washington State comes from just two stocks. Campton (1995) feels that any genetic effects caused by the importation of exogenous fish or gametes should not be considered caused by hatcheries per se, but rather an effect caused by a management process that used too few donor stocks.

The indefinite perpetuation of a population of fish is contingent upon maintenance of sufficient genetic diversity to allow adaptation to environmental changes (Thorpe et al. 1981). The extinction of a discrete population (or stock) is tantamount to a loss of genetic diversity within the species. The need for genetic material preservation is a universally accepted concept and is a fundamental purpose of the International Biosphere Reserve Program initiated by the United Nations. Virtually all biologists agree that a wide range of genetically diverse traits exists in naturally spawning wild stocks and that these are worth protecting (Kelly et al. 1990).

Genetic variability within and among fish populations constitutes the resource base that enables a species to survive and adapt to changing environmental conditions (Gharrett and Smoker 1993a, b; Gharrett et al. 1999b; Philipp et al. 1986). This variability is derived from a combination of many heritable traits developed and maintained through a complex set of long-term natural selective processes. Within a population, the number, frequency, and diversity of alleles present can measure genetic variability. Alleles are the variant forms of genes that are the basic units of heredity; the particular set of alleles present gives a stock its genetic uniqueness. In order to determine the extent to which two fish stocks differ genetically, scientists examine their genotypic and phenotypic structure. Genotypes can be studied qualitatively by molecular biologic techniques such as DNA sequencing, DNA and protein electrophoresis, and analyses with histochemical stains. Phenotypic differences between stocks can be teased apart to reveal the underlying genetic and environmental components by comparing phenotypes of individuals from different stocks raised in similar environments and measuring phenotypes of related individuals raised in contrasting environments. Both molecular/genotypic and phenotypic approaches can be used to estimate actual gene differences between stocks and the adaptive significance of those differences.

A great deal of protein electrophoretic information has been collected on salmon and on steelhead, rainbow, cutthroat, and brown trout *(Salmo trutta).* These data have been of value in a variety of ways and have enabled large genetically distinct groups of salmon to be identified. It is now known that three major, genetically distinct groups of sockeye salmon occur: one in Asia, one in Alaska to mid-British Columbia, and one ranging from mid-British Columbia south (Varnavskaya et al. 1994). These large genetically distinct groups may be comprised of many stocks. For example, a survey of electrophoretic diversity of 52 sockeye populations throughout Southeast Alaska identified three geographic groupings corresponding to the southern inside waters, the far southeastern islands (including Prince of Wales Island), and inside waters of northern and central Southeast Alaska (Wood et al.

1994). In British Columbia, five distinct groups of chum salmon, consisting of 83 separate stocks, have been identified (Kondzela et al. 1994).

A primary concern with hatcheries is their role in influencing genetic change (Utter 1998; Waples 1991). Indeed several studies have detected genetic differences between hatchery-produced and wild populations (Nielsen et al. 1994; Skaala et al. 1990, 1996). Unintended changes in allele frequencies or gene combinations in populations can potentially depress productivity (Busack and Currens 1995).

More recent studies have demonstrated that genetic changes may occur in farmed Atlantic salmon *(Salmo salar).* Altered allele frequencies and lowered heterozygosities in these fish relative to wild source populations have been recorded in Scotland and Ireland (Crozier 2000). An issue with farmed salmon involves the potential effects of interactions between them and the wild populations they come in contact with after escaping from sea pens. In Northern Ireland, the genetic status of a small wild population of Atlantic salmon was studied after an escape of farmed salmon from nearby sea cages led to interbreeding. Juvenile salmon in the first generation after interbreeding showed significant differences in the frequency and occurrence of some alleles. Observations of temporal change, the presence of a previously absent allele, and the genetic disequilibria reinforce a general conclusion that genetic change in the wild Atlantic salmon population reflects the influence of one or more episodes of escaped farmed salmon breeding in the river (Crozier 2000).

Direct genetic effects from hatchery production may occur if cultured fish hybridize with wild fish. Hybridization of different gene pools can theoretically have two important genetic consequences: loss of interpopulational genetic diversity and outbreeding depression (Waples 1991). According to Campton (1995), the natural spawning of hatchery fish in the habitat of wild populations can potentially lead to one or more of several outcomes: decreases in between-population genetic variation, decreases in within-population genetic variation, and decreases in fitness of the wild population (outbreeding depression).

Although hybridization typically increases the average gene diversity within the hybridizing populations, it also results in loss of gene diversity between populations (Waples 1991). With salmonids, the concern is that a variety of locally adapted stocks will be replaced with a smaller number of relatively homogeneous ones (Allendorf and Leary 1988). This process of consolidation tends to limit the evolutionary potential of the species as a whole (Waples 1991). The principal mechanisms leading to hybridization of hatchery and wild fish are (1) unintentional straying of hatchery fish into wild spawning grounds and (2) deliberate releases of hatchery fish to either increase population size or as conservation measures intended to save populations at risk or reintroduce native populations that have been eradicated. The reproductive effectiveness of hatchery-reared salmonids in the wild has been analyzed in several systems (Fleming and Petersson 2001; Garcia-Marin et al. 1999; Williams et al. 1996).

Decreases in fitness can occur when two genetically diverged or reproductively isolated populations interbreed (outbreeding depression). Extensive arguments have been made regarding the potential for outbreeding depression in Pacific salmon (Gharrett et al. 1999a). While many studies have demonstrated phenotypic differences between hatchery and wild fish, relatively few are clearly genetic. Examples of local adaptation appearing to have a genetic basis are rate of embryo development, homing ability, rheotactic swimming ability in emerging fry, outmigration timing of smolts, timing of returning adults, and variations of fecundity and egg size (Campton 1995; Hebert et al. 1998; McGregor et al. 1998; Smoker et al. 1998, 2000).

One often-mentioned negative effect from artificial propagation is a genetic change that reduces fitness for natural reproduction. Apparent loss of fitness in hatchery populations of resident trout has been demonstrated and widely accepted (Ryman and Utter 1987). However, this potential hazard has not been universally accepted as real or relevant to management of salmon. Skepticism stems from the anadromous life history of salmon. Culture of salmon involves rearing in captivity during freshwater stages and then release to use marine food supplies. Accordingly, measuring genetic changes and corresponding loss of fitness becomes complicated for populations experiencing natural conditions for much of their life cycle (Reisenbichler and Rubin 1999). Consequently, there is a reluctance to accept the argument that the genetic fitness of hatchery fish to produce viable fry declines substantially under natural conditions. There are also examples of hatchery fish successfully spawning in the wild like the chinook salmon in the Umatilla and Walla Walla tributaries to the Columbia River where they had been extirpated by dams, indicating that hatchery production is not necessarily correlated with a complete loss of fitness.

In Alaska, there exists a correlation in Prince William Sound of marine survival (one important component of fitness) in hatchery pink salmon and wild pink salmon. The high productivity estimated in both components suggests no measurable depression of saltwater fitness in either after more than ten generations of hatchery culture (W. Smoker, pers. comm.). However, Reisenbichler and Rubin (1999) argue that published information, along with studies in progress, collectively provide evidence that artificial propagation of steelhead trout, chinook and coho salmon, and probably other Pacific salmon results in significant genetic changes that lower fitness. At least eight studies have shown genetic differences between hatchery (ocean-ranched) and wild populations of Pacific salmon in behavioral or physiological traits that could reduce the fitness of hatchery fish (Reisenbichler and Rubin 1999). For example, development rate may change in response to novel water temperature regimes (Lannan 1980); time of spawning and growth rate may change due to either artificial or natural selection (Nickelson et al. 1986); and antagonistic behavior may increase (Swain and Riddle 1990), territorial behavior decrease (Norman 1987), and predator avoidance decrease (Berejikian 1995) in response to unnatural conditions in the hatchery.

Two published studies (Leider et al. 1990; Reisenbichler and McIntyre 1977) and three in progress (according to Reisenbichler and Rubin 1999) found the survival of naturally spawning hatchery fish was less than that for wild fish. The reproductive success of hatchery adults was lower than that of wild adults, and relative survival of hatchery fish consistently declined through successive life-history stages. These studies suggest the same conclusion: hatchery programs that rear steelhead trout or chinook salmon before release may genetically change the population and thereby reduce reproductive success when these fish spawn in natural systems (Reisenbichler and Rubin 1999). Reisenbichler and Rubin (1999) suggest that genetic change in fitness results from traditional artificial propagation of anadromous salmonids held in captivity for extended periods. In similar studies, Fleming and Gross (1989, 1992, 1993) demonstrated many changes in coho behavior, wherein hatchery coho were less able to compete for mates and had less ability to spawn successfully in the wild than did wild-origin fish. No comparable data are available for sockeye salmon, but it seems prudent to assume that the same conclusion holds. No comparable data are available for species (pink, chum) held in captivity for shorter portions of their life cycle, nevertheless similar though smaller genetic changes may be expected (Reisenbichler and Rubin 1999).

The potential for genetic interactions between hatchery and wild salmonid populations in the North Pacific has increased considerably since the 1970s. This is because efforts to mitigate losses to wild stocks from overfishing, destruction of habitat, and blockage of migratory routes have been focused on artificial production from hatcheries. This increases the pool of hatchery fish capable of breeding in the wild due to straying, and thus increased the opportunities for genetic interactions between wild and hatchery fish. Waples (1991) identifies three issues of concern: (1) direct genetic effects (caused by hybridization and introgression); (2) indirect genetic effects (principally due to altered selection regimes or reductions in population size caused by competition, predation, disease, or other factors); and (3) genetic changes to hatchery stocks (through selection, drift, or stock transfers) that magnify the consequences of hybridization with wild fish. Busack and Currens (1995) recognize four different types of genetic hazard: (1) extinction, (2) loss of within-population variability, (3) loss of among-population variability, and (4) domestication. According to Campton (1995), the potential genetic effects of hatcheries and hatchery fish can be grouped into three categories: (1) the genetic effects of hatcheries and artificial propagation on hatchery fish, (2) the direct genetic effects of hatchery fish on wild populations due to natural spawning and potential interbreeding, and (3) the direct genetic effects of hatchery fish on wild populations due to ecological interactions or management decisions that affect abundance.

One of the risks associated with hatcheries is domestication. Busack and Currens (1995) define domestication as the changes in quantity, variety, or combination of alleles within a captive population or between a captive population and its source population in the wild as a result of selection in an artificial environment. Waples (1999) defines it as any genetic change that results directly or indirectly from human efforts to control the environment experienced by a population. Considerable improvements have been made in both fish culture and fisheries management such as improved broodstock collection and mating protocols, more natural rearing conditions, focus on local broodstock, and release strategies more friendly to wild fish (Waples 1999). Although it may be possible to eliminate intentional selection from hatchery programs, it generally will not be possible to eliminate nonrandom broodstock sampling and unintentional selection that occurs in the hatchery environment.

The hatchery environment is different from the natural environment, and a successful hatchery program changes the mortality profile of the population and results in more fish surviving to enter the wild. Because of these factors, Busack and Currens (1995) concluded that some level of domestication is inevitable in a captive population. The management significance is simple: changing mating protocols will not eliminate genetic change from artificial propagation, and genetic changes in cultured populations cannot be avoided entirely. Although many factors can help reduce the nature and extent of the resulting genetic changes, they cannot be avoided entirely. Alternative mating protocols have been identified and more natural rearing systems are under development, but their effect on domestication has yet to be evaluated (Waples 1999).

A serious hatchery management concern is inbreeding, as it reduces the amount of genetic variation in a hatchery population. Repeated inbreeding may lead to inbreeding depression, the reduction of the mean phenotypic value. This may be greatest for traits that are components of fitness such as fertility, sperm viability, and survival of various life stages (Schonewald-Cox et al. 1983). Inbreeding depression and subsequent reductions in genetic variability have been demonstrated in cutthroat (Allendorf and Phelps 1980), brown (Ryman and Stahl 1980), and rainbow (Kincaid 1976) trout. The cited studies demonstrated several undesirable effects of inbreeding such as reductions in development, growth rate, survival, hatching, and fertility. Because traits related to fitness are susceptible to inbreeding depression, managers try to limit inbreeding. Salmon hatchery stocks have not generally experienced inadvertent inbreeding or measurable inbreeding depression as demonstrated in some wild and hatchery trout species (Lannan and Kapuscinski 1984). This is likely due to the comparatively large founder populations used in salmon hatcheries versus the limited broodstock used in trout hatcheries. A consensus of biologists is that the goal of hatcheries involved in fishery enhancement should be to make every effort to avoid inbreeding and maintain high fitness of the hatchery stock. However, many believe it is not possible to adequately mimic the successful reproductive strategies fish use in nature to maintain their genetic viability (Gharrett and Shirley 1985). Fish culturists, thus, have been encouraged to compensate for inadvertent loss of genetic variability by avoiding mating practices that foster loss of variability and by following certain procedures to minimize inbreeding. Best hatchery practices use a large founder or effective population size, provide crosses between wild and hatchery fish every season, use random mating, mate fish from all parts and age classes of a run, and avoid intentional selection of any given trait (e.g., large size, brightness) to help conserve genetic variability.

HOMING/STRAYING

What do homing and straying mean? For a wild fish, home is the natal stream where it incubated, hatched, and emerged. Nearly all salmon return reliably to their natal stream to spawn. Homing is a well-known feature of their biology; through it local populations are genetically isolated and are able to adapt to local environments. It is known that there is extensive variation among populations in many traits and this variation often has adaptive value. Such local adaptations have presumably arisen because homing fidelity leads to reduced levels of gene flow between populations using specific habitats and because there is genetic control of the traits that adapt the salmon for those habitats (Quinn 1997). For hatchery fish released at a remote location, the hatchery where they are reared and the release site could both be considered homes. While there is some tendency to return to the ancestral area, hatchery-reared salmon generally return to the site where they were released (Quinn 1997).

The other side of homing is straying. During straying, a small portion of salmon return to spawn in a stream different from their natal stream, maintaining genetic communication among local populations and, in turn, genetic diversity (Heggberget 1994). Patterns of straying vary between species and among populations and are poorly understood. Salmon move into non-natal streams for a variety of reasons. Upstream migration is characterized by a certain amount of exploratory movement. It is technically difficult to study straying, and it requires observations of marked fish. Consequently, most data come from observations of artificially cultured salmon (Quinn 1993).

Homing and straying have adaptive value for populations; the relative advantages may depend on environmental conditions, other life-history traits, and possibly the relative frequencies of homing and straying (Quinn 1997). A long-term balance between homing and straying is important to the fitness of salmon populations (Heggberget 1994). Straying from hatchery populations poses a risk to wild salmon populations because, if it results in interbreeding, genes from hatchery populations can be introduced into wild populations and adaptive gene complexes in wild fish can be disrupted (Gharrett 1994; Reisenbichler 1996).

There is concern that gene flow from hatchery strays may dilute the gene pool in populations of locally adapted wild fish. If a hatchery produces a large number of salmon, straying by even a small percentage of them has the potential to compromise the genetic makeup of nearby small wild populations. For example, in the 1980s strays from an ocean-ranching facility in Oregon were considered low (about 6%), but these strays accounted for about 74% of the fish in nearby streams (Quinn 1997). The absolute number of strays, a small percentage of the hatchery population, was large relative to the local wild population. While most concern is that strays will influence wild gene pools, wild salmon may also stray into a hatchery. One year an estimated 65% of wild coho salmon returning to the Yaquina River watershed in Oregon entered a local hatchery (Quinn 1997). Decoying of wild salmon into hatcheries can both reduce the number of wild fish and contribute to genetic mixing. Nonetheless, inclusion of wild salmon in hatchery broodstocks has often been practiced as it theoretically slows domestication and thus the potential effects of outbreeding depression (W. Smoker, pers. comm.).

Some natural colonization by salmon occurs. The relationship between straying and natural colonization is not well understood and little research has been done. In Alaska, new habitat appears as glaciers recede and this habitat is colonized as it becomes suitable for spawning (Milner 1987), hence colonization is now and recently has been important and frequent in most of the range of Pacific salmon. It is readily observed in recently glaciated landscapes and as a consequence of catastrophic landslides, volcanic eruptions, etc. It appears that soon after colonization straying rates may be high and that after populations become established only modest straying occurs (Quinn 1997). Nonetheless, in recent times translocation has been more common than natural colonization. Most translocations of salmon have been unsuccessful. There are, however, several successful examples: the inadvertent translocation of pink salmon into the Great Lakes as well as deliberate introductions of chinook and coho salmon into the Great Lakes resulted in rapid colonizations. The translocation of chinook salmon into one river in New Zealand led to unaided colonization of several river systems (Quinn 1997). There have also been successful and purposeful introductions of sockeye salmon into the upper Frazer River in British Columbia, Fraser Lake in Alaska, and Lake Washington in Washington. Evidence of reproductive isolation was found in Lake Washington sockeye after fewer than 13 generations (Hendry et al. 2000).

Little information exists on comparative straying rates between fish species. Straying is often thought to be greater in pink salmon than in other species, but definitive evidence is lacking. The most data exist for coho and chinook salmon and indicate large amounts of homing variability among populations, even within small geographical areas (Quinn 1997). Coho salmon straying rates are thought to be low in undisturbed populations (Dittman and Quinn 1996; LaBelle 1992). Most tagging occurs in hatchery fish; wild salmon are tagged less frequently and the data are seldom analyzed to produce estimates of straying. Consequently, most estimates of straying come from hatcheries. The overall estimate of homing in hatchery fish is 80% to 100% (Quinn 1997). Hatchery-produced salmon may or may not stray with the same frequency as wild salmon. Few studies have been conducted on hatchery and wild fish in the same area. Many experiments also suffer from a number of technical shortfalls, such as being poorly controlled, not being replicated, the study of homing variability being incidental to other goals, and failing to account for straying into and out of a population (only the dispersal of strays from the marking site is documented) (Quinn 1997). Quinn (1997) specifically mentions three studies of straying rates in salmon. In one case, wild chinook salmon in Washington State homed at a higher rate than did members of a hatchery population. On the other hand, hatchery and wild coho on Vancouver Island, British Columbia, did not significantly stray at different rates nor did Atlantic salmon in England.

Coded-wired tagging has provided a large database that can be used in homing studies. It is interesting to note that these data show a wide variation in spatial and temporal patterns of straying. The proportion or distance salmon stray is not the same in all hatcheries or regions, and the proportion of salmon straying into and out of a hatchery can vary considerably. Straying rates between 0% and 30% have been documented (Quinn 1997). In addition to differences in straying among rivers, straying can also vary from year to year. Straying variability can be associated with environmental changes like the eruption of Mount St. Helens or El Niño. Age at return can also contribute to straying variability, as older chinook salmon tend to stray more than younger fish (Quinn 1997). Even though chinook salmon hatcheries in Southeast Alaska are sited more than 50 kilometers from wild chinook rivers, tagged hatchery chinook have been detected among some wild spawning salmon in the region (Heard et al. 1995). One important study of wild pink salmon straying in Prince William Sound was not published because of concerns over direct effects of wire tags on homing and because it indicated very large rates of straying among populations. It is reviewed in the context of a later study of whether or not wire tags affect homing (Thedinga et al. 2000). This is more evidence that straying among pink salmon populations in western Prince William Sound is probably naturally large.

Some hatchery practices may promote straying. The most obvious is the transporting of fish from one locality to another. This is often referred to as "seeding" new habitat. Improper or incomplete imprinting may increase the straying rate of populations released from hatcheries. Fish released too long before or after the critical parr-smolt transformation may not experience the appropriate combinations of temporal, spatial, and physiological stimuli necessary for successful homing (Unwin and Quinn 1993). The site of release for hatchery fish can affect the amount of straying. Generally, local populations home better than transplanted ones; salmon home better to their natal site than a new site; and transplanted populations may show some tendency to return to their ancestral location (Quinn 1997).

Studies of small chum salmon populations on Vancouver Island indicate that degrees of genetic exchange between strays was lower than that inferred by the number of strays in the spawning area. Simply counting stray hatchery fish on spawning grounds may not provide a reliable estimate of the genetic interaction between hatchery and wild populations (Quinn 1997). It is not known whether straying hatchery salmon spawn successfully with wild salmon or if any loss of fitness and productivity occurs, but the potential risk is a strong concern within Alaska's ocean-ranching program (Smoker et al. 1999).

ECOLOGICAL INTERACTIONS

There exist many layers of biological diversity: within population, between population, behavioral, physiological, molecular, and ecological. Some stocks that have no obvious molecular differences may still have substantial ecological differences (e.g., run timing, preferences of substrate or habitat for redd construction and for incubation, intertidal versus upstream spawning, etc.). There are a number of ecological interactions that can take place between hatchery and wild fish. They can take the form of competition for food or space, predation, and negative social interactions when large numbers of hatchery fish are released in association with small numbers of wild fish. Given the controlled environmental conditions in a hatchery, it is not surprising that fish reared under these conditions are markedly different than their wild counterparts in behavior, morphology, survival, and reproductive ability. Artificial culture environments condition fish to respond to food, habitat, conspecifics, and predators differently than do wild fish (Flagg et al. 2000). Seemingly, the only similarities in hatchery and wild environments for salmonids are water and photoperiod (Reisenbichler and Rubin 1999). Flagg et al. (2000) summarized the major differences between hatchery and wild salmonids (Table 2).

Phenotypic differences observed between cultured and wild fish are both genetically and environmentally controlled. There is a positive relationship between smolt size and survival of hatchery fish that has encouraged hatchery managers to release larger smolts to maximize hatchery returns. The problem is that wild salmon life-history strategies have evolved based on the sizes they have been able to achieve under the temperature and nutrient limitations of the natural environment. Two potential negative impacts can result from this hatchery management scenario. One is the immediate impact on the ability of wild fish to avoid competition and predation pressures compounded by the presence of abundant, larger hatchery fish. The other, and perhaps more serious, is the long-term selective pressure being exerted on wild fish to accommodate the larger conspecifics in the ecosystem (Scientific Review Team 1998).

Salmon species that spend more time rearing in hatchery environments (coho, sockeye, chinook) are more

Table 2. Relative differences between wild and hatchery salmonids (Flagg et al. 2000).

Wild Salmonid		Hatchery Salmonid
Lower survival egg to smolt *Higher* survival smolt to adult	***Survival***	*Higher* survival egg to smolt *Lower* survival smolt to adult
Efficient forager *Lower* aggression *Lower* social density *Higher* territorial fidelity *Disperse* in migration *Bottom* habitat preference *Flee* from predators	***Behavior***	*Inefficient* forager *Higher* aggression *Higher* social density *Lower* territorial fidelity *Congregate* in migration *Surface* habitat preference *Approach* predators
More variable shape *Brighter* color *Larger* kype	***Morphology***	*Less* variable shape *Duller* color *Smaller* kype
Smaller eggs *Fewer* eggs *Higher* breeding success	***Reproduction***	*Larger* eggs *More* eggs *Lower* breeding success

susceptible to subtle environmental changes than are those that do not (chum, pink). Although hatchery rearing increases egg-to-smolt survival, the post-release survival of cultured salmonids is often lower than wild-reared fish. Research conducted since the 1960s suggests that post-release survival of hatchery fish represent both adaptive differences between hatchery and wild populations and environmental differences between hatchery and natural rearing environments (Flagg et al. 2000). Poor survival of both hatchery strains in natural environments and wild strains in hatchery environments were found in steelhead trout (Reisenbichler and McIntyre 1977). In other steelhead studies, naturally spawned and reared hatchery offspring experienced greater mortality than offspring of wild fish during all three major life-history stages (Chilcote et al. 1986; Leider et al. 1990). These studies suggest that adaptive differences occurred between hatchery and wild populations in a relatively short time period.

Many studies have indicated that the hatchery-rearing environment can influence the behavior of salmon. Levels of aggression and antagonistic behavior appear to differ between domesticated and wild populations. Juvenile salmonids from domesticated and wild populations appear to demonstrate adaptive differences in antagonistic behavior, and the behavioral development of domesticated and wild fish appears dependent upon their rearing environment (Flagg et al. 2000). Cultured and naturally-reared salmonids respond differently to habitat. In most cases wild fish use both riffles and pools in streams, while hatchery fish primarily use pool environments. Hatchery strains are typically more surface oriented than are wild fish. Most of the innate surface orientation of hatchery fish is likely an adaptive response to the practice of introducing food at the surface of the water (Flagg et al. 2000). Predation is a major factor affecting the survival of hatchery-reared fish. Experimental evidence indicates that hatchery strains of salmonids have increased risk-taking behavior and lowered fright responses compared to wild fish (Flagg et al. 2000).

Another impact of hatchery management on the ecological status of wild fish involves pre-smolt releases on stream carrying capacity through added competition. Hatchery fish are seldom released in numbers that are related to the carrying capacity of the receiving stream. The pre-smolt juveniles and any residuals will compete with their wild counterparts and lower the wild fish success by changing optimum habitat use of the wild fish (Scientific Review Team 1998). Hatchery coho releases into naturally seeded streams in British Columbia led to little demonstrable increase in smolt production on the east coast of Vancouver Island. Irvine and Bailey (1992) evaluated the success of outplanted coho juveniles and concluded that supplementation prior to summer low-flow periods did little to increase production. Thus, for releases to be successful in increasing smolt yield, releases would need to be timed to take advantage of available habitat after summer low-flow periods had ended (summer low flows created survival bottlenecks).

Hatchery practices have altered reproductive behavior by relaxing selection pressure on secondary sexual characteristics (kype) used in breeding competition in the wild, while increasing selection pressure on primary sexual characteristics (such as quantity and quality of eggs). Relaxation of breeding competition led to hatchery coho salmon with less pronounced kypes and breeding colors while developing larger and more numerous eggs than comparably sized members of the wild stocks from which they were derived (Fleming and Gross 1989). The same researchers found that hatchery male coho allowed to spawn naturally were less aggressive and less active than wild males. Either inadvertently or intentionally, hatcheries often develop strains that spawn at different times than their ancestral stock. The most common practice is to select for early run timing by spawning a disproportionate higher percentage of the early returning fish. An advantage of a temporal separation from a management perspective is to separate stocks in a fishery and minimize interbreeding. A disadvantage is that if interbreeding does take place, the progeny of domestic strains and wild-domestic crosses may emerge prior to peak abundance of natural aquatic food sources and thus suffer higher mortality rates. Granath et al. (2000) found significant differences in hatch times for crossed coho salmon in Southeast Alaska.

MARINE ENVIRONMENT

Climatological Influences

Despite increased awareness of the marine effects on salmonid growth and survival, scientists still have a rather poor understanding of the ecology of salmon once they leave freshwater (Brodeur et al. 2000). There exists a lack of comparable understanding of the marine environment to that of freshwater despite evidence that this habitat may be more significant to population variability. An incomplete understanding about the basic aspects of salmon biology in marine waters has hampered the ability to predict natural variability in salmon production (Brodeur et al. 2000).

Although climatological factors such as precipitation affect freshwater systems as well as salmon survival, scientists believe that ocean conditions contribute to variability in salmon survival and growth, particularly in the first few months after leaving freshwater. Early marine survival is governed in part by both water temperature and salinity. This period of ocean entry is a critical one in the life history of salmonids. The timing of ocean entry has evolved through natural selection to minimize predation and maximize growth (Pearcy 1992). Although the most visible part of a salmon's life cycle is completed on the freshwater spawning grounds, most growth and about one-half of mortality occurs in the ocean.

Following entry into the ocean, most North American salmon begin a rapid and highly directed migration north and west. They remain exclusively upon the narrow coastal shelf, migrating up and around at least as far as the Aleutian Islands and do not enter the open ocean for many months. The confinement of the entire North American population of juvenile salmon to a narrow strip of coastal ocean makes them especially vulnerable to problems resulting from competition for food or climate change (Welch 1999). The climate of the North Pacific alternates between two general ocean states. One is dominated by a weak winter Aleutian Low (pressure) resulting in negative sea-surface temperature anomalies (cooling). The second occurs in response to an eastward displacement and intensification of the Aleutian Low and is characterized by positive sea-surface temperature anomalies (warming) (Cooney and Brodeur 1998).

Numerous recent studies indicate that fluctuations in climate are the major source of widespread, regionally, coherent changes in the marine survival rate for many salmon species (Hare et al. 1999). Mysak (1986) showed that El Niño affected both Bristol Bay and Fraser River sockeye salmon populations. Several studies have connected dramatic changes in Alaska and West Coast salmon production to decadal scale climate regime shifts in the North Pacific (Beamish and Bouillon 1993; Francis and Hare 1994; Francis and Sibley 1991; Hare 1996; Hare and Francis 1995). This climate phenomenon is known as Pacific Decadal Oscillation or PDO. It is described as a pan-Pacific, recurring pattern of ocean-atmosphere variability that alternates between climate regimes every 20 to 30 years (Hare et al. 1999). Hare et al. (1999) found that salmon catches in Alaska have varied inversely with catches from the U.S. West Coast during the past 70 years. Results of their analysis suggest that the spatial and temporal characteristics of this inverse catch/production pattern are related to climate-forcing events associated with the PDO.

Clues left by decaying salmon at the bottom of lakes in Alaska point to climate change and overfishing as causes of the large swings in the size of the state's salmon runs. Records of prehistoric salmon abundance have been reconstructed from analysis of stable nitrogen isotopes in sediment cores (Finney 1998). Cores from Karluk Lake show minimum salmon escapement occurring during the mid-1900s, early 1800s, early 1700s, and mid-1500s. Relatively high values were observed from the early 1900s, late 1700s, mid-1600s, and late and early 1500s. In general, sockeye salmon runs were larger during periods of warm climates and smaller during cold periods.

There is increasing evidence of persistent patterns and synchronous changes in the ocean environment in the Pacific Ocean. Evidence is also accumulating to show that large-scale trends in Pacific salmon abundance are linked to trends or regimes in climate and resulting ocean conditions (Beamish et al. 1999). The fluctuations in salmon abundance have been shown to correspond to shifts in zooplankton abundance that can be linked to physical changes in the ocean. The trends in salmon abundance are not necessarily the same for all areas of the ocean, as climate shifts can cause large-scale oscillations in ocean productivity with regional impacts. Fluctuations in Pacific salmon abundance in this century are synchronous with large fluctuations in Japanese sardine abundance, a relationship that can be traced back to the early 1600s. The synchrony in the fluctuations suggests that Pacific salmon abundance may have fluctuated for centuries in response to climate (Beamish et al. 1999).

Since 1976 a major change has occurred in the Northeast Pacific Ocean, with unfavorable ocean conditions for salmonids in the Coastal Upwelling Domain and highly favorable conditions farther north in the Coastal Downwelling and Central Subarctic Domains and the Bering Sea. High sea levels and warm temperatures along the coast, an intense Aleutian Low, and weak upwelling are associated with these changes (Pearcy 1996). In the late 1970s, an intensification of the Aleutian low-pressure system in the North Pacific Ocean apparently resulted in a warming of the sea surface along the northern North America coast and cooling farther offshore (Cooney and Brodeur 1998). This event was associated with exceptionally strong year-classes of many marine and anadromous fishes and signaled the beginning of a period of increasing productivity for salmon north of British Columbia. Conversely, this shift in ocean climate produced an opposite effect on fish off the Pacific Northwest, most notably on coho salmon (Mantua et al. 1997). Coded-wire tagging studies indicate that changes in ocean conditions could be partially responsible for survival declines of coho and chinook salmon in the Pacific Northwest (Coronado and Hilborn 1998a).

Favorable ocean conditions, growing enhancement operations, and improved management practices have led to dramatic increases in Pacific salmon production over the last 20 years. Production in 1994 was about double the amount in the mid-1970s. The largest increases have been for pink and sockeye salmon. Evidence exists for at least two previous ocean states or regimes affecting Alaska salmon, one ending in the 1940s after which production fell and the other concluding in the late 1970s and followed by increasing production for two decades (Beamish 1993; Beamish et al. 1999).

Salmon sensitivity to temperature is widely recognized and any climate change is likely to affect survival rates. Long-term impacts from any carbon dioxide-induced global warming may prove to have major implications for sustainability of salmon. If salmon continue to maintain the sharp thermal limits that they have been shown to follow over the past 40 years, then any global warming could adversely affect them. Warming oceans could force salmon to migrate farther north in search of suitable temperatures or force them deeper out of the sunlit surface water where food is greatest (Welch 1999).

Ocean Carrying Capacity

Large-scale climatic factors affect ocean productivity and thus carrying capacity for salmon (Cooney and Brodeur 1998). Review of research on the physical and biologic factors affecting ocean production indicated that climate-induced variation in productivity and fishing are the two major factors affecting ocean production of salmon (Myers et al. 2000).

Carrying capacity is a measure of the biomass of a given population that can be supported by a given ecosystem. It changes over time with the abundance of predators and resources. Carrying capacity is determined by several processes including primary productivity, food-web dynamics, number of trophic links, ecological efficiencies, fraction of production consumed by competitors, and predation. In addition, the carrying capacity of a species is modulated by the size of the region inhabited, which in turn is influenced by temperature and availability of food (Pearcy et al. 1999). All of these factors are dynamic, fluctuating over seasons, years, decades, and millennia.

Dramatic changes have occurred in the North Pacific Ocean in recent years. Some recently documented changes are significant warming of the ocean during the 1990s, shallower winter mixed-layer depth and reduction of nutrients entrained into the euphotic zone, changes in seasonal maxima of a dominant subarctic copepod with peak biomass occurring earlier in the upper water column, unusual coccolithophore blooms in the Bering Sea, and regions of depleted nitrate during the 1990s (Pearcy et al. 1999). All of these changes may affect the carrying capacity of the North Pacific. The ocean's carrying capacity for salmon is dynamic in time and space, constantly changing on interannual, decadal, centennial, and millennial time scales.

Humans impact estuarine and coastal regions through activities that may exacerbate global warming, by introducing exotic species, by creating chemical pollution, and by physically altering habitats (e.g. clear-cut logging practices, building subdivisions, dredging, etc.) and bottom fishing (Brodeur et al. 2000). When these anthropogenic factors are set against the backdrop of natural variability, their effects on ocean carrying capacity may be further exaggerated (Brodeur et al. 2000). The estuarine and ocean carrying capacity for salmon may be compromised by the attempt to make up for declining natural runs by increasing hatchery production, thus leading to density-dependent food limitation in winter months (Pearcy et al. 1999).

Density-Dependent Competition

A fundamental assumption of ocean ranching has been that salmon use only a small fraction of available coastal and ocean forage. Food limitations in these environments were not given serious consideration until salmon began returning at smaller sizes and older ages (Cooney and Brodeur 1998). Several investigators in the 1970s estimated that salmon consumed only a few percent of the zooplankton and that salmon production could be increased significantly. Since these early studies, several salient estimates have changed. Even though only a fraction of the primary production is used by salmon, as recognized in earlier studies, the high trophic level of salmon and the complex food web with many other consumers and competitors suggest that substantial increases in the production of salmon in ocean waters of the Pacific are unlikely (Pearcy et al. 1999). Declines in both the size and size at age of salmon harvested and increases in the age of maturity have been documented over the past 20 years around the Pacific Rim (Bigler et al. 1996). This is important evidence for density-dependent growth and may suggest that the carrying capacity of oceanic waters of the North Pacific is being approached for salmonids (Pearcy et al. 1999).

Competition for food among salmon has been shown. The diet of pink salmon may change between years of strong and weak year classes, with a shift from zooplankton to more nutritious prey like squid. Squid compete with immature salmon for zooplankton, while providing a food source for maturing salmon. Both the growth and diet of chum salmon have been correlated with the abundance of pink salmon; when pink salmon are less common, chum salmon may shift their diet from gelatinous zooplankton to more nutritious prey (Pearcy et al. 1999).

Releases of hatchery fish increased rapidly after the 1960s and are presently between 5 and 6 billion, about 25% of the total number of juvenile salmon entering the ocean (Heard 1998). According to Beamish et al. (1997), of the total number of juvenile salmon entering the ocean, about 84% of chum, 23% of pink, and 5% of sockeye salmon are produced at hatcheries. Estimates of annual food consumption by pink salmon in Prince William Sound rose from less than 100,000 metric tons prior to 1976 to more than 300,000 metric tons after 1988, when hatchery production began dominating returns (Cooney and Brodeur 1998). Recent levels of wild and hatchery production in the North Pacific Ocean have placed substantial forage demands on ocean-feeding domains (Pearcy et al. 1999). Recent studies in Prince William Sound found Dungeness crab megalopae composed 35% to 65% of the stomach contents of pink salmon. Despite the curtailment of fishing on these crabs in Prince William Sound, their productivity remains low. The large numbers of hatchery pink salmon being released in Prince William Sound could be having a significant and unintended impact on other ecosystem components like crab (Boldt et al. 2001).

Evidence for a limited ocean carrying capacity comes from negative relationships between numbers of fish and their rates of growth. Density-dependent growth of some stocks has been suggested (reviewed by Pearcy 1996). Klovach and Gritsenko (1999) suggested that limited ocean carrying capacity might explain why fish became smaller during periods of high salmon abundance. There has been a decrease in mean body length, mean weight, and fecundity and an increase in the mean age of matured fish. A decrease in size of the fish may lead to corresponding decreases in fecundity and energy reserves available for the freshwater migration. In 1994 a mass softening of chum salmon tissue was discovered in Asian salmon. Some of these fish also had unusual elongated body shapes. The causes behind this appear to be dietary. Studies have documented a shift in the diet of Asian chum salmon to include a large quantity of low-caloric forage like salps, jellyfish, and ctenophores, which were only rarely found in other salmon. In the 1960s, when salmon abundance was much lower, these organisms were not so prevalent in the diet of chum salmon. Previously, these organisms were part of chum salmon diets only in years of high pink salmon abundance (Klovach and Gritsenko 1999). Klovach and Gritsenko (1999) concluded that the high numbers of Japanese hatchery chum salmon feeding in the ocean creates densities of fish which, if not exceeding carrying capacity, then at least considerably exceed an optimal density. Some Russian scientists believe that competition with the chum juveniles of Japanese hatchery origin during the marine-rearing phase has prevented the recovery of wild Russian chum stocks (Radchenko 1998). These studies are consistent with the hypothesis that hatchery releases by one country along the Pacific Rim may affect the size, number, and value of adult salmon returning to other countries thereby creating scientific and management problems of international concern.

In contrast to growth, survival does not appear to be as density dependent. Survival of hatchery-produced pink and chum salmon in Alaska appears to mirror that of wild fish from the area surrounding the hatchery: when survival of hatchery salmon is high, wild stocks from the surrounding area also survive in greater numbers. In some years, this appears to be a localized phenomenon with different survival rates within a region. Coronado and Hilborn (1998b) presented data summarizing ocean survival over time and hatchery releases for Pacific coho populations. The graph of ocean survival for southern British Columbia coho showed a strong inverse relationship to the total number of hatchery-produced salmonids released. Salmon survival shifts appear to be caused by changes in local environmental conditions, possibly related to fluctuations in climate (ADF&G 1999; Coronado and Hilborn 1998a, b).

FISHERY MANAGEMENT IMPLICATIONS

Forecasting future trends in the abundance of fish populations has not been particularly successful. Historically, many hypotheses about the relationship between fish populations and marine environmental parameters have been suggested. Only in the last several years have these hypotheses become more refined. It is possible that improved forecasting will result from an increasing understanding of the synchronicity between persisting trends in climate/ocean conditions and patterns of marine survival of salmon (Beamish et al. 2000).

Beamish et al. (1999) and others have noted persistent trends in the dynamics of fish populations in relation to climate/ocean conditions and term these regimes, which they define as a multiyear period of linked recruitment patterns in fish populations. If natural trends in Pacific salmon abundance occur, then fisheries management should account for this phenomenon when developing strategies. Beamish et al. (2000) found that survival of coho salmon from California to British Columbia decreased after 1989 in synchrony. This large-scale synchronous change over the southern range of coho salmon distribution indicates linkage with a common event. Shifts in the pattern of April flows in the Fraser River and the intensity of the Aleutian Low appeared to be indices to this change in survival. The trend towards low marine survival may persist as long as the trends in the climate indicators do not change.

Survival rates for coho salmon were estimated for all coded-wire tagged fish in the Pacific Northwest between 1971 and 1990. During this time there was considerable geographic variation, with most regions south of northern British Columbia showing declining survival and more northern areas showing increasing survival. According to Coronado and Hilborn (1998b), ocean conditions have been the dominant factor affecting coho survival since the 1970s and a major reduction in exploitation rates is necessary to maintain the populations. Moreover, during lower productive regimes there is concern as to what impact large numbers of hatchery-produced salmon may have on wild populations, and it has been suggested that prudent management practices be adopted during less productive regimes. High harvest rates in ocean fisheries targeted toward abundant hatchery stocks make conservation of wild stocks especially difficult when ocean productivity is low (Beamish et al. 1997).

Environmental indices changed around 1990, indicating the productive North Pacific Ocean regime of the 1980s was changing. There were continued increases in much (but not all) of Alaska marine productivity and a concomitant sharp drop in southern British Columbia—but not northern British Columbia ocean productivity (Welch et al. 2000). Hatchery enhancement has contributed to increased salmon production in the late 1900s, especially in Japan and Alaska. If the ocean carrying capacity is being reached, increased hatchery releases may not increase the biomass of salmon produced. Catches of pink, chum, and sockeye salmon by the major salmon-producing countries in the 1900s shows high catches in the early and late 1900s and low catches in the mid-1900s (Beamish et al. 1997). The early and late 1900s correspond to favorable ocean/climate conditions and the mid-1900s to unfavorable. The high catches in the early 1900s were almost entirely wild fish, while those of the late 1900s included a significant number of hatchery fish.

Given the two favorable ocean environmental regimes, about the same number of fish were produced but hatchery-produced fish appeared to replace wild fish in the late 1900s. Estimates of the percentage of hatchery-produced coho salmon in the Strait of Georgia have been made over time. The percentage of hatchery fish has increased from about 25% in the early 1980s to nearly 50% in 1990 to approximately 75% in 1998 (Noakes et al. 2000b). These estimates suggest a gradual replacement of wild fish with hatchery fish over time. Evidence from Prince William Sound also suggests that hatchery pink salmon replaced rather than augmented wild production (Hilborn and Eggers 2000). A critique of this analysis, based on different assumptions and statistical analysis, questions the rate at which hatchery-produced pink salmon may be replacing wild salmon (Wertheimer et al. 2001).

MANAGEMENT ISSUES

The reassessment of management's fundamental assumptions about the role of hatchery production has led to much public debate, most recently over the federal proposal to breach or remove the four Snake River dams to aid in the recovery of salmon. This would have been an unthinkable action just a few years ago. To avoid the problems of the past, fundamental assumptions need continuous examination and management programs must be flexible to change, when warranted, in response to new information (Lichatowich et al. 1999). Throughout their history, hatchery programs have exhibited a chameleonic behavior, changing to match the social and economic environment while retaining the same conceptual foundation. In the nineteenth century fish culture offered a means to restore eastern U.S. fisheries, provide an income for farmers, and increase the food supply of an expanding nation. The agricultural goals of the U.S. fish culture movement dictated the kinds of scientific questions that were relevant and may explain why fisheries science developed its own ideas and theories distinct from those of systems ecology (Bottom 1996). These ideas emphasized the improvement of fish through hatchery selection as well as the introduction and acclimatization of species in new environments.

New understanding about fish adaptations to their environment along with the recent collapse of salmon production in the Pacific Northwest have undermined the old agricultural model of applied fisheries science (Bottom 1996). Presently, there is a continuing search for an analytical solution to a value-based problem. According to Bottom (1996), a more important role for fisheries than ecosystem management will be to foster a better understanding and appreciation of human ecosystem dependence.

Throughout their history, hatchery programs have been implemented under the assumption that relationships among reproduction and harvest could be manipulated through human intervention to be simpler and more predictable. Production has largely been brought under control in some watersheds like the Columbia River, where 80% of the salmon is of hatchery origin. Even though most of the salmon are of hatchery origin, less salmon are returning to the Columbia River Basin today than at any time in recorded history. The hatcheries have failed to achieve their original objective of replacing production (Lichatowich et al. 1999).

The use of hatcheries to supplement depleted stocks has generated nearly endless disagreement. Faced with the general collapse of salmon in the Pacific Northwest, four independent scientific advisory boards have or are currently examining restoration programs in various parts of the region (Independent Science Group 1996; National Fish Hatchery Review Panel 1994; National Research Council 1996; Scientific Review Team 1998). The conclusions and recommendations of these different groups were almost identical and the following points were identified as common denominators (Flagg and Nash 1999):

- Hatcheries have generally failed to meet their objectives.
- Hatcheries have imparted adverse effects on natural populations.
- Managers have failed to evaluate hatchery programs.
- Hatchery production was based on untested assumptions.
- Hatchery production should be linked with habitat improvements.
- Genetic considerations have to be included in hatchery programs.
- More research and experimental approaches are required.
- Stock transfers and introductions of non-native species should be discontinued.

- Artificial production should have a new role in fisheries management.
- Hatcheries should be used as temporary refuges, rather than for long-term production.

The Northwest Power Planning Council's Independent Science Advisory Board concluded that it is skeptical of the efficacy of hatcheries in fisheries enhancement but does not discount their functionality in fish and wildlife restoration (Independent Science Group 1996).

The above evaluations and conclusions are focused on hatchery operations in the Pacific Northwest, and it remains to be seen to what degree they apply to Alaska's ocean-ranching program. Proponents of Alaska's system are quick to claim that hatchery programs in Alaska have either met their objectives or have been closed down. They note that about a quarter of all hatcheries have been closed, that mixed hatchery and wild stock fisheries have been managed based on the productivity of wild stocks, and that sufficient resources have been devoted to evaluation of hatchery efficacy. Alaska has, to some degree, learned from mistakes made elsewhere and Alaska's management reflects this.

Recently, there has been a growing appreciation that long-term sustainability of salmon requires conservation of natural populations and their habitats (National Research Council 1996). As a result of this paradigm shift, many hatcheries are now being asked to minimize impacts to natural populations (Waples 1999). The recent examination of salmon management's conceptual framework has led to the recommendation that it be replaced with an alternative (Independent Science Group 1996). The new framework proposes that restoration activities must consider the entire ecosystem. It recognizes the complexity of salmon life history and that the biodiversity of wild stocks must be conserved (Independent Science Group 1996). Biodiversity has become a familiar term outside of scientific circles. Ways of measuring and mapping it are advancing and becoming more complex, yet a consensus about how to conserve biodiversity is still developing and the resources available to manage diminishing biodiversity are scarce. One problem is that policy decisions are frequently at the local scale, whereas biodiversity issues are more often regional or national in scope.

Many have argued that critics of hatcheries often confound biologic factors intrinsic to hatcheries with effects of fisheries management. One should be careful not to exaggerate the dichotomy between biology and management. No fish hatchery exists in a vacuum, and they are usually designed to meet one or more management objectives. Many management factors involve both fisheries management and fish culture. For example, selective breeding, when it occurs, is carried out by fish culturists to achieve a fisheries management objective. Two factors that are primarily a function of management are mixed-stock fisheries and stock transfers (Waples 1999).

In an analysis of salmon and steelhead hatchery production, Miller (1990) studied over 300 projects in North America. Among his observations was that evidence for the successful rebuilding of runs was scarce. Projects were more successful at just returning fish. Adverse impacts to wild stocks had been shown or postulated from about every type of hatchery introduction. He concluded that there were no guarantees that hatchery production could replace or consistently augment natural production. Miller found that most supplementation projects have been so poorly documented that it is impossible to determine what has happened. Cuenco et al. (1993) also examined historical cases of successful and unsuccessful supplementation and found quite a few successful supplementation projects. Among the best known is the case of successful supplementation of the Lake Washington sockeye, which were originally from the Skagit River. Repeated stocking of Skagit sockeye started the current run of Lake Washington sockeye.

MIXED-STOCK FISHERIES

A major management concern involves different exploitation rates between hatchery and wild stocks mixed in commercial and/or sport fisheries. Overharvest of wild stocks in mixed-stock fisheries could have a profound impact on survival of wild stocks. When abundant hatchery stocks are targeted for high harvest, less abundant wild stocks cannot withstand the high exploitation rates, resulting in underescapement of wild fish. The optimum harvest rate of wild stocks is much lower (generally 40% to 75%) than that of hatchery stocks (90% to 95%) (Wright 1981). It also should be noted that depressed stocks, such as the interior Fraser River coho, could not withstand exploitation rates in excess of 10%. The protected hatchery environment generally allows a high rate of fertilized egg to fry or juvenile survival while, in contrast, the average overall survival rate of wild salmonids from fertilized egg to adult is lower. Subsequently, fewer fish (or eggs) are needed to maintain a hatchery population. In mixed-stock fisheries, it is difficult (if not impossible) to harvest one stock at the optimum level without over- or underharvesting other stocks (Ricker 1973). Where overfishing of wild stocks has been permitted, adverse effects have been measured. Some examples are disappearance of the summer chinook stock in the Columbia River, disappearance of coho stocks in the Columbia and Snake Rivers, and decline of wild stocks caught in the highly productive channel-raised sockeye fishery of Babine Lake, British Columbia.

Ideally, establishment of separate fisheries on wild and hatchery stocks (usually involving geographically separate terminal fisheries) is the preferred management technique. This usually involves manipulations through reprogramming of hatchery production that would directly impact harvest in specific fisheries. This can involve changes in stocks reared at a hatchery or changes in the hatchery environment that would affect migration behavior and availability of returning adults to a fishery. The most common technique is establishment of a terminal fishery. The goal is to allow as much exploitation in mixed-stock fisheries as practical and then to harvest all remaining hatchery adults in a terminal single-stock fishery (Evans and Smith 1986). However, a terminal fishery is not always possible because of geographic or socioeconomic barriers. When a mixed-stock fishery is inevitable, the recommended first priority is to reduce exploitation rates to accommodate the less productive wild stocks (Argue et al. 1983; McDonald 1981; Ricker 1973). Risks to wild stocks from overharvest can be reduced by siting facilities where harvests are not mixed or by using tags to identify hatchery fish in mixed harvests. In areas of mixed-stock fisheries, large-scale marking programs (thermal otolith marks) have been initiated to contain the risk (Smoker et al. 1999).

Patterns of salmon migration complicate management. Conservation of weak stocks by time and area closures may not be a good option for stocks that pass through numerous fisheries over an extended period en route to their spawning streams. Artificial production of salmon stocks through hatcheries has the potential to adversely affect wild runs via overexploitation. This concern can be amplified by the geographic location of hatcheries and release sites. Long-term declines have occurred in coho stocks with high exploitation rates from Georgia Strait, British Columbia (Shaul 1994).

The generic management goal of maximizing harvest underscores hatchery management philosophy. The management concept of maximum sustainable yield has not only impacted escapements of wild fish in mixed-stock fisheries, but has also affected nutrient input from carcasses that enriched otherwise nutrient-impoverished streams. The dependence on artificial production in the Pacific Northwest has exaggerated the deficit in nutrient transfer of many drainages from that historically experienced. Consequently, reduction of carcass contribution to nutrient loads in salmon-spawning streams is an indirect ecological impact of hatchery management (Scientific Review Team 1998). Nutrients delivered from the ocean by salmon are important in the nutrient-poor streams of Alaska.

ALASKA'S HATCHERY PROGRAM

HISTORY

Due to the depressed state of Alaska's salmon fishery in the late 1960s and early 1970s, many (including fishermen, processors, and legislators) felt it was time to attempt to propagate fish by means of hatcheries. The public and the Alaska legislature seemed more enthusiastic about the program than professional fishery biologists. State and federal fishery management agencies often expressed concerns about adverse biologic consequences. The biologists stated a preference for rehabilitating wild stocks over the propagation of hatchery stocks. Questions such as genetic intermingling, disease, and competition were raised, but it was decided to proceed with an eye toward protecting wild stocks. Concerns were known to legislators but seemed speculative in the face of cries for relief from communities. It was hoped that potential problems could be mitigated by exercising reasonable precautions, such as regional management plans and careful siting of hatchery facilities to segregate hatchery and wild stocks (Alaska Senate 1992).

By 1968 public concern over the depressed salmon fishery was high, and a general obligation bond authorization for $3 million to build hatcheries was passed by the Alaska legislature and overwhelmingly approved by the public. In 1971 the legislature created the Fisheries Rehabilitation, Enhancement, and Development Division (FRED) of ADF&G to operate public hatcheries and coordinate fish enhancement activities. In 1973 the United Fisherman's Association (UFA) was formed, organizing commercial fishermen at the state level. Fishermen's groups like UFA were a driving force behind the state's salmon hatchery programs (Alaska Senate 1992), and they soon lobbied for private nonprofit (PNP) hatchery programs. In 1974 the Alaska legislature passed the Private Salmon Hatchery Act. It was amended in 1976 and 1977 to add the Fisheries Enhancement Loan Program, which provided for low-interest loans to regional aquaculture associations and added a provision for the formation of regional associations that would own and operate the PNP hatcheries (Olsen 1994).

It soon became evident that the costs of developing private salmon hatcheries were far greater than anticipated. New methods of financing construction and operation were sought (Alaska Senate 1992). Accordingly, the 1974 law was amended the following year to allow proceeds from the sale of salmon or salmon eggs to be applied to debt retirement as well as to operating costs. In 1975 another state low-interest financial source was made available to hatcheries when the commercial fisheries loan program was expanded to include hatcheries. In 1977 legislation was passed to create a Fisheries Enhancement Revolving Loan Fund that relaxed conditions for obtaining loans. In 1988 legislation was passed to allow private aquaculture corporations to take over operations of state hatcheries. FRED was combined with the Division of Commercial Fisheries by executive order in 1993 and subsequently most FRED hatcheries were transferred to regional associations under long-term cooperative lease arrangements (Heard 1996). ADF&G closed 3 hatcheries and transferred 13 to the PNP corporations. Except for the Deer Mountain hatchery, these were owned by the state but operated for ADF&G under contract with various PNPs. Deer Mountain was owned by the City of Ketchikan and operated by ADF&G; today it is owned by the Ketchikan Indian Corporation. The four state hatcheries that produced fish for recreational fisheries were transferred to the ADF&G Division of Sport Fish in 1993. In 2000 the state's Crystal Lake Hatchery was contracted to the Southern Southeast Regional Aquaculture Association, leaving only the two sport fishery hatcheries near Anchorage directly under ADF&G's control.

Since 1980, five state hatcheries have been closed that were not taken over by PNPs: East Creek, Russell Creek, Big Lake, Sikusuiliaq, and Clear. East Creek was an experimental sockeye hatchery in Bristol Bay that encountered infectious hematopoietic necrosis virus (IHNV) disease problems and was shut down in 1981. Russell Creek was a chum hatchery in the False Pass area that was closed in 1992. It was poorly sited from a management perspective, causing allocation conflicts between sockeye and chum salmon and between different management-area chum salmon runs. The Big Lake hatchery was a sockeye hatchery that had a history of low cost-recovery harvest and closed in 1993. Sikusuilaq was an experimental chum hatchery near Kotzebue above the Arctic Circle that was closed in 1995. The Russell Creek, Big Lake, and Sikusuilaq hatcheries were all ultimately closed as cost-reduction measures by ADF&G (S. McGee, pers. comm.). The Clear hatchery was a Division of Sport Fish hatchery that was closed in 1997; its mission was absorbed by the Division's hatcheries in Anchorage. Table 3 summarizes significant events in Alaska's fishery enhancement program.

PLANNING

The commissioner of ADF&G is authorized to designate regions of Alaska for the purpose of salmon enhancement and to develop and maintain Regional

Table 3. Time line of fishery enhancement events in Alaska (McNair 2001).

Year	Event	Number of State Hatcheries	Number of PNP Hatcheries	Number of Federal Hatcheries
1934	Federal research station Little Port Walter constructed			1
1950	Federal hatchery at Auke Creek constructed			2
1953	1 territorial hatchery constructed (Kitoi Bay)	1		
1954	1 territorial hatchery constructed (Deer Mountain)	2		
1958	1 territorial hatchery constructed (Ft. Richardson)	3		
1965	1 state hatchery constructed (Fire Lake)	4		
1969	1 state hatchery constructed (Crystal Lake)	5		
1971	Fisheries Rehabilitation, Enhancement, and Development (FRED) Division created by legislature			
1973	2 state hatcheries constructed (Crooked Creek and Gulkana) State enhancement projects at Starrigavan and Halibut Cove started	7		
1974	2 state hatcheries constructed (Beaver Falls and East Creek) Legislature authorizes permits for PNP hatchery operators to salmon ranch	9		
1975	4 PNP permits issued (Sheldon Jackson (#3), Port San Juan (#2), Perry Island (#1), and Sandy Bay (#4) 2 state hatcheries constructed (Big Lake and Tutka)	 11	4	
1976	AS 16.10.375 passed, designating regions for Regional Planning Teams and enhancing salmon 1 state hatchery constructed (Elmendorf) 2 PNP permits issued (Burnett Inlet (#5) and Kowee Creek (#6)	 12	 6	
1977	1 PNP permit issued (Gunnuk Creek (#7) 2 state hatcheries constructed (Klawock and Russell Creek) State enhancement project at Karluk Lake started	 14	7	
1978	1 PNP permit issued (Whitman Lake (#8) 2 state hatcheries constructed (Cannery Creek and Hidden Falls)	 16	8	
1979	3 PNP permits issued (Sheep Creek (#11), Meyers Chuck (#10), Salmon Creek (#9) 1 state hatchery constructed (Snettisham) 1 state hatchery closed (Fire Lake)	 17 16	11	
1980	1 PNP permit issued (Burro Creek (#12) 2 state hatcheries constructed (Clear and Main Bay) 1 hatchery at Tamgas Creek constructed (Metlakatla Indian Community/BIA)	 18	12	 3

Planning Teams (RPTs). RPTs currently have three primary duties: (1) develop and update regional comprehensive salmon plans, (2) review hatchery permit applications, and (3) review hatchery operations. RPTs comprise three members of the local aquaculture association and three members of ADF&G. Criteria that are used to determine public benefit from the hatchery program include: (1) whether or not the hatchery makes a significant contribution to the common property fishery, (2) whether or not the

Year	Event	Number of State Hatcheries	Number of PNP Hatcheries	Number of Federal Hatcheries
1981	I state hatchery closed (East Creek) 2 state hatcheries constructed (Sikusuilaq and Trail Lakes) 4 PNP permits issued (Medvejie (#16), Port Armstrong (#13), Solomon Gulch (#15), Salmon Creek (#14) I PNP permit revoked (Salmon Creek (#9)	17 19	 16 15	
1982	2 PNP permits issued (Eklutna (#17) and Favorite Bay (#18)		17	
1983	3 PNP permits issued (Neets Bay (#19), Crittenden Creek (#22), and Esther (#20) I state hatchery completed (Broodstock Development Center)	 20	20	
1984	I PNP permit issued (Santa Ana (#21)		21	
1985	I PNP permit issued (Port Camdem (#23)		22	
1986	I PNP permit issued (Beaver Falls (#24)		23	
1987	State enhancement projects at Starrigavan and Halibut Cove started			
1988	Aquatic Farm Act signed; statute passes allowing contracting of hatchery operations 4 state hatcheries contracted to private sector (Kitoi Bay, Trail Lakes, Cannery Creek, Hidden Falls) 4 PNP permits issued (Hidden Falls (#28), Cannery Creek (#26), Trail Lakes (#27), Kitoi Bay (#29) I state hatchery constructed (Pillar Creek) 2 PNP permits revoked (Sandy Bay (#4) and Salmon Creek (#14)	 16 17	 28 26	
1990	CSHB432 becomes law prohibiting finfish farming in Alaska I PNP permit issued (Bell Island (#30)		 27	
1991	5 state hatcheries contracted to private sector (Main Bay (#31), Tutka, Gulkana (#30), Pillar Creek (#38), and Beaver Falls (#24) – Beaver Falls and Tutka tallied elsewhere Portions of 6 state hatcheries paid for by private or federal funds	 12	 30	
1992	I state hatchery closed (Russell Creek) 2 PNP permits issued (Haines projects (#34) and Port Graham (#33) I PNP permit revoked (Meyers Chuck (#10) FRED Division merged with the Commerical Fisheries Division to form the Commercial Fisheries Management and Development (CFMD) Division	11	 32 31	
1993	3 state hatcheries transferred from CFMD Division (Broodstock Development Center, Elmendorf, & Ft. Richardson) 2 state hatcheries contracted to private sector (Crooked Creek and Klawok) I state hatchery closed (Big Lake)	 9 8		
1994	4 PNP permits issued (Tutka (#32), Crooked Creek (#35), Klawok (#36), Deer Mountain (#37) I state hatchery contracted (Deer Mountain) Ft. Richardson Hatchery merged with Broodstock Development Center	 7 6	35	
1995	I PNP hatchery under new management (Klawok (#38) I state hatchery transferred from CFMD to Division of Sport Fish (Crystal Lake) I state hatchery closed (Sikusuilaq)	 5		
1996	I state hatchery contracted (Snettisham (#39) I state hatchery transferred from CFMD Division to Division of Sport Fish (Clear) 3 PNP permits revoked (Crittenden Creek (#22), Santa Ana (#21), and Favorite Bay (#18)	4	36 33	
1997	I state hatchery closed (Clear) 2 state contracted PNP hatcheries closed (Beaver Falls (#24), and Crooked Creek (#35) I PNP hatchery closed & reopened under new management (Burnett Inlet (#5), now #40)	3	 31 31	
1998	I PNP hatchery closed (Eklutna (#17)		30	
2000	I state hatchery contracted to private sector (Crystal Lake Hatchery)	2	31	3

Note: Perry Island, Kowee Creek, Port Camden and Bell Island are not active PNP sites (total = 27 active operational PNPs) hatchery production protects wild stocks, (3) whether or not the hatchery operation is compatible with the regional comprehensive salmon plan, and (4) whether or not the site for the hatchery is appropriate (Alaska Board of Fisheries 1999).

Regional comprehensive salmon plans have been completed by RPTs for the following regions: Southern Southeast, Northern Southeast, Yakutat, Prince William Sound/Copper River, Cook Inlet, Kodiak, Chignik, Alaska Peninsula/Aleutian Islands, Bristol Bay, Yukon River, and Norton Sound/Bering Strait. Regional comprehensive planning progresses in stages. Phase I sets the long-term goals, objectives, and strategies for the region. Phase II identifies potential projects and establishes criteria for evaluating the enhancement and rehabilitation potentials for salmon in the region (McGee 1995). Many regions, including Northern and Southern Southeast, Prince William Sound/Copper River, Yakutat, Cook Inlet, Kodiak, and Bristol Bay completed their plans in the 1980s. Others, like Chignik, Alaska Peninsula/Aleutian Islands, and Norton Sound/Bering Strait, completed their plans in the 1990s. Most of these plans were written for a 20-year period and some, like Northern and Southern Southeast were updated in the 1990s. One region, Prince William Sound/Copper River, developed a third planning phase in 1994 that incorporated the allocation and fisheries management plans of the Board of Fisheries with hatchery production plans. Each region approached the development of its regional comprehensive plan differently and the resulting documents reflect this (Krasnowski 1997).

PNP statutes provide for regional aquaculture associations comprised of representative fishery resource user groups within regions. In order to obtain a hatchery permit, these groups must be PNP corporations. Aquaculture associations can (1) build and operate hatcheries, (2) assist ADF&G in developing regional salmon plans, (3) authorize tax assessments on commercially caught salmon to support ranching (a 1%, 2%, or 3% assessment is chosen by vote of the members), and (4) provide for the sale of a portion of returning hatchery fish to help cover operational costs and repay state loans (Heard 1996). Before an aquaculture association or other PNP corporation can build and operate a hatchery, it must obtain the necessary hatchery permits from ADF&G.

PERMITTING

The permit application procedure for a PNP hatchery is described in Title 5 of the Alaska Administrative Code (AAC 40.100–40.990). Application procedures include pre-application assistance, management feasibility analysis, application form and fees, determination of acceptance by ADF&G for formal review, RPT review, completeness determination by the commissioner, and a provision for reconsideration. The ADF&G Divisions of Commercial Fish, Sport Fish, and Habitat and Restoration; the principal pathologist; and the principal geneticist review the hatchery permit. A public hearing and full review by other state and federal agencies is required through the coastal zone consistency process. A basic management plan (BMP) is developed as part of the permit. The BMP includes a description of the facility, special harvest areas, broodstock description and development, and hatchery stock harvest management. The permit application process is shown in Figure 2. In 1975 the first PNP permits were issued for four locations: Perry Island, Port San Juan, Sheldon Jackson, and Sandy Bay. Forty PNP permits have been issued since inception of the program. The PNP permit process usually takes one to two years to complete (McGee 1995). A hatchery permit is nontransferable.

When a permitted hatchery becomes operational, an annual management plan (AMP) is developed for each year of operation. Specific plans for egg takes, cost recovery, harvests, fry and smolt releases, and marking and recovery are included and approved in this plan. AMPs are developed by ADF&G in conjunction with the operator and are reviewed by the fisheries management divisions and RPT before approval by the commissioner (McGee 1995). Any PNP permit holder is to submit an annual report to

ADF&G, which is to include but not be limited to information pertaining to species; broodstock source; and number, age, weight, and length of adult returns attributable to hatchery releases (ADF&G 1996). Even though statutes permit inspection of a hatchery by ADF&G personnel at any time the hatchery is operating, the annual reports along with the AMPs constitute the primary PNP-monitoring vehicles. The PNP regulation process is shown in Figure 3.

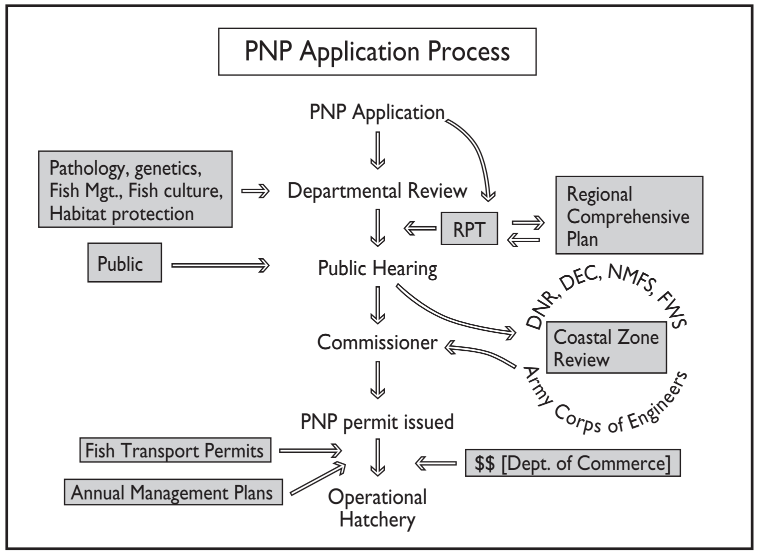

Figure 2. PNP application process chart (McGee 1995).

Alaska statutes (AS 16.10.400–430) place responsibility for the PNP program with the commissioner of ADF&G. It is the exclusive authority of the commissioner to issue permits for the construction and operation of salmon hatcheries. The commissioner may place conditions on a permit. All PNP permits include a fish transport permit (FTP). Title 5 ACC 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 that person holds an FTP issued by the commissioner (McGee 1995). The principal pathologist and geneticist, as well as the region's regional supervisors for the ADF&G divisions review all FTPs. Additional PNP permit conditions may include the following: no placement of salmon eggs or resulting fry into waters of the state except as designated in the permit, restrictions on the sale of eggs or fry, no release of salmon before ADF&G approval, destruction of diseased fish, and ADF&G control of where salmon are harvested by hatchery operators.

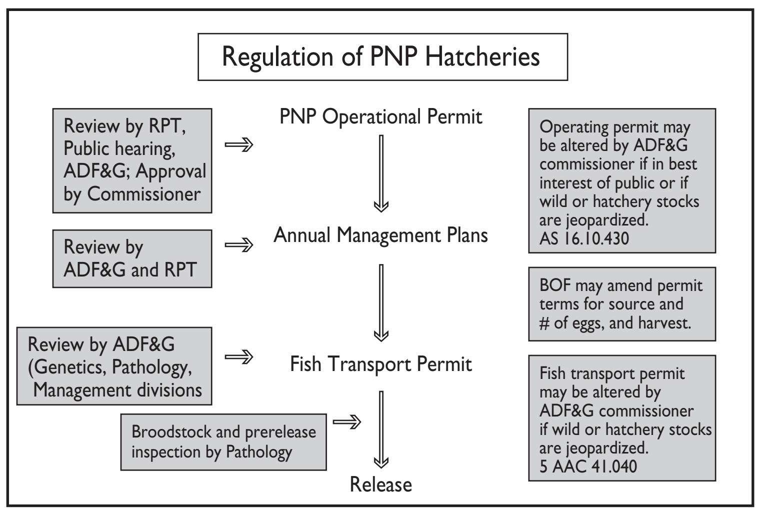

Figure 3. Regulation of PNP hatcheries (McGee 1995).

The commissioner of ADF&G has the power to revoke a hatchery permit if he or she determines that after five years from the date of issue, the permit holder has not undertaken substantial work to operate a facility in compliance with the terms and conditions specified in the permit. Seven hatchery permits have been revoked to date: Salmon Creek #9 and #14, Crittendon Creek, Santa Anna, and Favorite Bay due to lack of progress toward operating a facility; Sandy Bay as the result of a natural disaster (landslide); and Meyers Chuck because of a violation of the terms of the permit when an unauthorized habitat alteration in an anadromous stream took place (S. McGee, pers. comm.).

The commissioner can also consider a permit alteration, suspension, or revocation based on an internal review that deems the hatchery operation performance is inadequate. RPTs use the following criteria to review, evaluate, and make recommendations to the commissioner: (1) hatchery survival standards, (2) the transport of broodstock from wild sources, (3) hatchery contribution to common property fishery, (4) hatchery impact on wild stocks, (5) fulfillment of production objectives, and (6) mitigating circumstances (ADF&G 1996). More recently, several of the amendments have resulted in a downward adjustment of allocated egg takes due mostly to lack of facility capability or use. Since 1999 the hatcheries in Prince William Sound have had their permits adjusted downward about 150 million pink salmon eggs. Also in 1999, the hatchery at Solomon Gulch lost its allocation for fall chums due to nonutilization and a concern for potential overfishing of local wild coho salmon stocks (S. McGee, pers. comm.). Permitted hatchery capacity for chum salmon in Southeast Alaska was reduced by 119 million eggs between 1997 and 1998 and by another 90 million in 2000.

POLICIES

As described below, various policies were implemented in Alaska to guide hatchery development and to protect wild stocks.

In 1975 ADF&G formulated a provisional Finfish Genetics Policy, which was revised in 1978 following legislative approval of the PNP program. It was revised again in 1985 by a review team comprising scientists from ADF&G, PNP organizations, the University of Alaska, and the National Marine Fisheries Service. The policy represents a consensus of opinion and is intended to be reviewed periodically to ensure the guidelines maintain consistency with current knowledge (McGee 1995). The revisions clarify the rationale for the guidelines and reduce ambiguity in the policy. The current policy contains recommendations designed to protect the genetic integrity of wild stocks. It restricts stock transport, calls for identifying significant or unique stocks and establishing wild stock sanctuaries, and helps maintain adequate genetic variability in hatchery-produced stocks to enable them to adapt to changing environmental conditions (Genetic Policy Review Team 1985). The policy includes considerations for selective breeding practices to ensure diversity within hatcheries and from donor stocks.

Alaska's Fish Resource Permits Policy was approved in 1994 to replace an outmoded 1983 policy. This policy covers the various types of permits required for the collection and/or transportation of live fish in any life stage used for scientific, educational, propagative, or exhibition purposes (McGee 1995).

Alaska's Fish and Shellfish Health and Disease Control Policy was completed in 1988. Its purpose is to prevent the dissemination of infectious diseases to fish and shellfish without creating impractical constraints for aquaculture (McGee 1995). Regulations require that the state pathologist approve any transfer of live salmon and that all salmon eggs brought into any hatchery be disinfected. The policy also includes a separate fish culture document (Sockeye Salmon Culture Manual) that outlines breeding and hatchery protocols for sockeye salmon (Smoker et al. 1999). These special considerations for sockeye salmon were deemed necessary because of the persistent threat of IHNV disease in culture facilities. ADF&G may inspect hatchery facilities at any time they are operating. Each facility is inspected at least every other year by state pathology staff, and each broodstock is examined for disease prior to use in a hatchery (McGee 1995).

In 1992 Alaska's Salmon Escapement Goal Policy was approved to establish the basis and mechanisms for setting escapement goals for the state's wild salmon stocks. Then, in 2001 the Board of Fisheries adopted a revised policy as regulation.

It is intended to support the statute to provide for a wild-stock priority while managing fishery resources on a sustainable yield basis. In 1992 the Board of Fisheries also adopted the Policy for the Management of Mixed Stock Salmon Fisheries (5 ACC 39.220). This regulation makes conservation of wild stocks and sustained yield the highest priority when allocating salmon resources (McGee 1995).

In 2000 the Board of Fisheries adopted the Sustainable Salmon Fisheries Policy to further effect sustainable fisheries management. The policy is based on five central principles: (1) protect wild salmon and habitat, (2) maintain escapements, (3) apply effective management system, (4) encourage public support and involvement, and (5) manage conservatively when there is uncertainty (ADF&G and Alaska Board of Fisheries 2000). This policy recognizes the need to protect wild salmon stocks, as well as to conserve and maintain normal ecosystem functions.

SITE SELECTION

According to various ADF&G salmon plans, hatchery sites and remote release sites were to be selected to minimize the chance of returning hatchery stocks mixing with wild stocks. During the early 1970s, some biologists testified in legislative resource hearings concerning PNP hatcheries that intermingling of returns of wild and hatchery stocks could be minimized if barren systems were used as hatchery sites. By this time, however, several hatcheries (Ft. Richardson, Fire Lake, Deer Mountain, Kitoi) had already been placed on producing streams. In addition, the then director of the FRED Division felt siting was not a problem and that it was better to have the problem of too many fish returning (regardless of where they came from) than not enough (Alaska Senate 1992).

In general, the siting of the PNP hatcheries was determined in the permit review process by ADF&G and PNP staff. In 1974 an ADF&G policy on permitting PNP hatcheries in Alaska addressed permitting on streams depleted of salmon or for insignificant producers. Most early decisions were based on the reviewers' knowledge of the area and relevant fisheries. Hatchery siting decisions were often determined by who owned the land and the reliability of the water source. In the case of chinook salmon, however, guidelines were written in 1983 to minimize the chance of hatchery and wild stock mixing. No hatcheries in Southeast Alaska were to be built on streams with natural runs of chinook salmon (Denton et al. 2000). Current permit regulations state that a hatchery is to be located in an area where a reasonable segregation from natural stocks occurs. However, when feasible, it is also to be placed in an area where returning hatchery fish will pass through traditional salmon fisheries (ADF&G 1996). Given the nearly statewide distribution of salmon in Alaska, it is nearly impossible to avoid siting a facility close to a salmon stream.

STOCK SELECTION

In general, the broodstock for hatcheries is to come from stocks as close to the facility as practical. The 1985 Finfish Genetics Policy prohibits transport if there would be significant interaction with "significant or unique wild stocks." Just what "significant" or "unique" stocks are is rather vague and is left up to ADF&G interpretation. The policy prohibits transport of salmon between regions of Alaska and from outside the state; it permits transport within regions only with consideration of the risks. The policy has been enforced with rigor in preventing transfers of salmon to Alaska from outside of the state. Coho and chinook are the only species of salmon that have been transplanted in Alaska from outside the state. Several coho and chinook stocks were brought into the state from Washington in the 1960s and 1970s. Most of these fish came from either the Green River or Carson hatcheries and were placed in Alaska hatcheries at Crystal Lake, Fire Lake, Starrigavan, and Fort Richardson. The last egg transfers to come into Alaska from outside the state were chinook from Carson, Washington, in

1971 to Little Port Walter; coho from Green River, Washington, in 1972 to Crystal Lake; and coho from the Columbia River in 1979 to Tamgas Creek. There were also a few uses of broodstock from inside the state but outside of the region. For example, coho eggs were taken in the 1970s from Bear Lake (Seward) and Ship Creek (Anchorage) and used at Crystal Lake (Southeast). (See Appendix A for broodstock source for hatcheries).

In Southeast Alaska, eight ancestral chinook salmon broodstocks (Andrew Creek, Big Boulder Creek, Chickamin River, Farragut River, Harding River, King Salmon River, Tahini River, and Unuk River) have been used in hatchery production. Presently five of these broodstocks are being used, with two (Andrew Creek and Chickamin River) accounting for the majority of releases since 1988. The Broodstock Development Project at Little Port Walter maintains Chickamin and Unuk stocks in isolation from each other (and all are wire tagged) (W. Smoker, pers. comm.). Andrew Creek stock has been used at five hatcheries (Crystal Lake, Gastineau, Hidden Falls, Medvejie, and Sheldon Jackson). Most hatcheries in Southeast are 50 to 240 kilometers from any endemic chinook salmon stock (Denton et al. 2000).

Numerous coho broodstocks have been used in Alaska hatcheries; over 30 have been used in Southeast. Sashin Creek, a stock from the southern end of Baranof Island, is one of the more common and farthest traveled stocks. It is found at four hatcheries: three on Baranof Island (Hidden Falls, Medvejie, Port Armstrong) and one near Juneau (Auke Creek). However, there is no hatchery production of coho at Auke Creek. Sashin Creek coho were transferred to Auke Creek as part of a "norms of reaction" experiment in the early 1980s, but all were marked and none were allowed entry to Auke Creek (W. Smoker, pers. comm.). Also, Sashin Creek coho are not released at Medvejie. They are transported from the hatchery back to several hanging lakes (inaccessible to naturally-spawning salmon) on the east side of Baranof Island between Port Armstrong and Hidden Falls. Ketchikan Creek fish (originally from Reflection Lake) are used as broodstock for three hatcheries: Deer Mountain, Tamgas Creek, and Burnett Inlet. Most of the other hatcheries use stocks in close proximity to the hatcheries.

There are over 20 stocks being used for chum salmon broodstock, most in Southeast Alaska. All chum salmon broodstock sources have come from within the same region as the hatchery. Hidden Falls hatchery is the most used broodstock by other hatcheries and originated with three stocks: Kadashan, Clear, and Seal Bay. In turn, this broodstock has been used at the Medvejie Creek, Gastineau, Gunnuk Creek, and Indian River hatcheries. The three Gastineau hatcheries have the most complex mixture of broodstock, with at least six stocks being incorporated. The Whitman Lake and Neets Bay hatcheries both used the same three stocks (Carroll, Cholmondelay, and Disappearance) to start their broodstock. Cholmondelay and Disappearance Creeks are fall-run stocks and Carroll River is a summer-run stock.

Pink salmon are raised at fewer hatcheries in Alaska than are coho or chum. In Southeast, pinks are being raised at four hatcheries with about 10 stocks being used as broodstock. Most of these have come from sources close to the hatcheries and, with the exception of the Gastineau hatcheries, little broodstock interchange has taken place among hatcheries. In Prince William Sound, pinks make up the largest number of salmon being cultured. They are raised at four hatcheries with broodstock coming from Cannery Creek and Solomon Gulch, both of which are in close proximity to the hatcheries. The Koernig hatchery used three principal sources for broodstock (Duck/Galena Bay, Larson, and Ewan). This broodstock was also used for the Norenberg hatchery. Of these only Duck/Galena Bay made any significant contribution in even years. Larson (the site of Koernig hatchery) is an intertidal waterfall with a few fish spawning below it. Only Ewan contributed significantly in odd years. The broodstocks at Koernig have been moved to the Noerenberg hatchery on the western side of Prince William Sound.

Sockeye salmon are the least cultured salmon in Alaska due to a difficulty in culturing them because of their high potential for disease. There are currently five hatcheries plus two incubation box facilities raising sockeye salmon. Most of the hatchery sockeye broodstock come from remote sites (distant from the hatchery location), and the progeny are released back at these sites.

STRAYING

Straying rates for pink salmon from hatcheries in Prince William Sound specifically, and among wild pink salmon populations generally, may be significantly higher than for other salmon species (Sharp et al. 1993). Joyce and Evans (1999) used recoveries of thermally marked otoliths to determine if pink salmon strays from hatcheries could be detected adjacent to three Prince William Sound hatcheries (Noerenburg, Koernig, and Cannery Creek) in 14 selected streams in Prince William Sound. They purposefully studied streams where straying from the hatcheries would be most likely detected and did not systematically sample streams across Prince William Sound. The proportion of hatchery salmon in stream escapements ranged from 26% to 97%.

An obvious explanation for the large contribution of hatchery salmon to wild escapements in Prince William Sound lies in the numerical dominance of hatchery over wild salmon runs. In 1997 the commercial fishery in Prince William Sound harvested about 25 million hatchery pinks and 1.2 million wild pink salmon (Joyce and Evans 1999). The proportion of hatchery salmon in stream escapements may become large even when straying rates are small. The study also showed that straying was highly correlated with distance between the hatchery and donor stream origin. The Noerenburg and Koernig hatcheries had straying rates five times those for the Cannery Creek hatchery. The broodstock from the Noerenburg hatchery was obtained from pink salmon spawning streams located distant from the facility, while the Cannery Creek hatchery stock was obtained from Cannery Creek. Broodstocks from the Koernig and Noerenburg hatcheries originated from streams considered unstable, and they may have more tendencies to stray (Joyce and Evans 1999). This is probably due to the fact that these broodstocks were from intertidal spawning stocks that probably have intrinsically much lower homing fidelity than do upstream stocks (W. Smoker, pers. comm.). High rates of straying in Prince William Sound relative to other locations may reflect recent geologic instability in the Sound. The 1964 earthquake caused widespread habitat destruction in the intertidal zone of streams. A large proportion of Prince William Sound pink salmon are intertidal spawners, and a high level of straying was likely among returning salmon that found natal streams no longer accessible (Halpuka et al. 2000).

In another study using thermal mark recoveries in Southeast Alaska, returning pink salmon of Prince William Sound hatchery origin were found over 450 direct distance miles away from the hatchery (Agler et al. 2000). Thermally marked otoliths from chum salmon originating in Gastineau hatchery near Juneau have been recovered in watersheds near the hatchery (Smoker et al. 1999).

FISH CULTURE

In order to help maintain genetic variance in hatchery stocks, several guidelines for fish culture were outlined in the Finfish Genetics Policy. These include the following: a single donor stock cannot be used to establish or contribute to more than three hatchery stocks; a minimum effective population *(Ne)* of 400 should be used for broodstock development and maintained in hatchery stocks (however, small population sizes may be unavoidable with chinook and steelhead); and to ensure all segments of the run have the opportunity to spawn, sliding-scale egg takes for donor stock transplants will not allocate more than 90% of any segment of a run for broodstock. There is also a caution in the policy to keep the male-to-female sex ratio as close to 1:1 as possible (Genetic Policy Review Team 1985).

The AMP for each hatchery outlines their respective fish culture procedures and is reviewed by ADF&G genetics staff for adherence. The FTP is used to authorize the broodstock and stocking location requested by each PNP in their respective AMPs. Prior to 1998 there was a potential for genetics review of the FTP without knowing what was in the AMP. ADF&G altered its review procedures and now staff geneticists routinely review both the FTPs and AMPs prior to their being approved by the commissioner (D. Moore, pers. comm.).

GENETIC DIVERSITY

Identification of the origins of salmon harvested from a mixed-stock fishery is a management concern as well as a conservation concern for biological diversity. The ADF&G Gene Conservation Laboratory has successfully used genetic data to identify regional stock components for selected populations of chinook, chum, pink, and sockeye salmon.

Data have been collected throughout the North American range for chinook salmon. Allele frequency differences are sufficient to identify differences among chinook stocks from eight large regions: Western Alaska, Southeast Alaska, British Columbia (non-Frazier), Fraser River, Washington Coastal, Puget Sound, Columbia River, and California-Oregon. At least two distinct lineages of chinook are present in Alaska: one composed of populations from Southeast and one of populations from west and north of the Copper River. Populations within Southeast Alaska are more divergent than those in the Western region. Three distinct groups are apparent within Southeast Alaska: Chilkat River, King Salmon River, and remaining Southeast populations (Crane et al. 1996).

A comparison of allele frequency data collected in western Alaska with data available for Pacific Rim chum populations suggests that populations of the Alaska Peninsula-Gulf of Alaska lineage were derived from Cascadia (the Pacific Refugium) and belong to a larger southern lineage, which includes populations from Southeast Alaska, British Columbia, and the Pacific Northwest. In contrast, populations from Northwest Alaska appear to be derived from a northern lineage with affinities to Asian populations. Populations of the northwest lineage occur in the largely unglaciated areas of Alaska north of the Alaska Peninsula, and the more southern lineage occurs in the glaciated and unglaciated areas of the Alaska Peninsula, Kodiak Island, and Southcentral Alaska (Seeb and Crane 1999).

ADF&G has conducted a pilot study of pink salmon from Northwest Alaska to Northwest Washington using DNA markers. Populations were found to be organized by latitude; populations that are geographically farthest apart are also genetically most divergent. In Prince William Sound, ADF&G found genetic differences between even- and odd-year fish and within-year differences between early and late spawning aggregates. Genetic differentiation has been found among streams and within streams, as well as between tidal and upstream spawning fish. These differences indicate that pink salmon in Prince William Sound are not one randomly interbreeding population, but rather a collection of populations with restricted gene flow (ADF&G 2001).

ADF&G has developed a sockeye salmon database of genetic information for the Upper Cook Inlet and Chignik River drainages and is currently working to expand the database to include Kodiak Island and the Bristol Bay drainages.

DISEASE PROTOCOLS

Risks of infectious disease dissemination have been reduced by rigorous enforcement of Alaska's Fish and Shellfish Health and Disease Control Policy (Holmes and Burkett 1996), which restricts transfer of salmon and requires inspection of facilities and examination of salmon. There have been several instances where IHNV disease has been detected in hatchery sockeye, and the fish have been destroyed. Because of this threat, Alaska has a sockeye-breeding protocol for hatcheries.

FISHERIES MANAGEMENT

Management of Alaska's salmon fishery began when Congress passed the Alaska Salmon Fisheries Act in 1889 to protect and regulate Alaska's fisheries; it was amended several times between 1900 and 1906. The Act prohibited obstruction of spawning streams and any fishery above tidewater in streams less than 500 feet wide (Pennoyer 1979). Prohibiting fishing out of stream mouths adversely affected fishery efficiency in order to reduce the prospect of overharvesting, but it necessarily established mixed-stock fisheries that are prone to overharvesting the weak stocks. With Alaska statehood in 1959, the legislature invested authority for management of Alaska's fisheries to ADF&G and the Alaska Board of Fish and Game (later separated into the Board of Fisheries and Board of Game). ADF&G was given authority to promulgate emergency orders to summarily open or close seasons or areas or to change weekly closed periods (Pennoyer 1979). The governor appoints members to the Board of Fisheries (also known as the Board of Fish). The Board of Fisheries has no administrative, budgeting, or fiscal powers but is charged with allocating salmon within and among different user groups and promulgating management regulations that are enforced by ADF&G. The Board of Fisheries holds hearings regarding regulations and policies affecting Alaska's fisheries throughout the state and maintains a system of advisory committees to obtain local input in making regulations.

Management of resources in waters within three nautical miles from shore is the responsibility of the State of Alaska (Pennoyer 1979). ADF&G manages the salmon fishery in discrete management areas. These include six fish and game resource management regions (Southwest, Southcentral, Southeast, Arctic, Interior West, and Interior Central) and four commercial fisheries management regions (Southeast, Central, Arctic-Yukon-Kuskokwim, and Westward). Because of the discrete nature of these areas, there is no comprehensive salmon management plan for the entire state and each management area has its own goals and objectives. In addition, ADF&G may promulgate certain statewide management policies that are signed by the commissioner of ADF&G, such as its Finfish Genetics Policy.

The mixed-stock and mixed-species nature of the Alaska fishery, as well as its system of allocation to specific user groups, creates complicated management issues. Even though the commercial fishery is by far the largest, the recreational, subsistence, and personal use fisheries all target on salmon. Meeting the needs of these diverse user groups while maintaining salmon population levels can be problematic. Although goals and objectives may differ from management area to management area, the ultimate salmon management goal statewide is to harvest surplus salmon from each stock while providing adequate escapement levels.

Article VIII of the Alaska Constitution mandates that renewable state resources be managed in a sustainable manner. This is the guiding principle behind the state's current fisheries management, whose goal is to produce maximum sustained yield. According to Alaska Statute (Title 16), it is the policy of ADF&G to manage for wild salmon stocks by ensuring adequate escapement. The commissioner approved the Salmon Escapement Goal Policy in 1992 to establish the basis and mechanisms for setting escapement goals for wild salmon stocks. The Alaska Board of Fisheries adopted a revised Salmon Escapement Goal Policy in 2001. This policy affirms the mandate to manage fishery resources on a sustainable yield basis.

A further relevant historical point is to note the growing dependency of commercial fisheries in Southcentral and Southeast on hatchery production. For example, salmon fisheries in the Gulf of Alaska are notable because hatcheries produce the majority of some salmon species in some areas and, in specific fisheries, the majority of salmon harvested.

Within this region, 56% of the salmon in the traditional commercial harvest were of hatchery origin in 1999, and the percentage is higher if cost-recovery fisheries are included. In Prince William Sound in particular, hatchery production provides a majority of the pink and chum salmon harvested and a substantial fraction of the sockeye and coho salmon harvested. In 1999 hatchery pink salmon contributed 84% of the number of pink salmon harvested by commercial fisheries in Prince William Sound (P. Mundy, pers. comm.).

Special Harvest Area

The harvest of salmon in Alaska, regardless of whether the fish were naturally or artificially propagated, may be conducted only pursuant to regulations adopted by the Board of Fisheries. The harvest of salmon returning to a PNP hatchery is governed by regulations adopted by the Board of Fisheries and is a common property fishery. The operation of PNP hatcheries brings with it the obligation to provide the hatchery operator with a certain portion of the hatchery run for recovery of operational costs and broodstock to sustain production. Cost-recovery harvests and broodstock collection take place within a designated area termed the special harvest area (SHA). Where hatchery returns enter a segregated location near the release site and can be harvested without significantly affecting wild stocks, a SHA is designated for each hatchery by regulation adopted by the board or by emergency orders issued by the commissioner. A PNP permit holder may harvest salmon for the hatchery only in the applicable SHA. However, this does not prevent a SHA from being open to commercial, sport, or subsistence fishing. Harvesting of salmon within the SHA, whether by the hatchery or the common property fishery, is opened or closed by regulation or emergency order. SHA boundaries are set in 5 AAC 40 or in a PNP permit issued by the commissioner (ADF&G 1996). A SHA is very similar to a terminal harvest area, except that a terminal harvest area is solely a common property fishery and does not have to be related to a hatchery.

Cost-recovery requirements and broodstock needs are determined in advance of the season and published in the AMPs. Based upon returns to the SHA, interception of hatchery returns by the common property fishery is adjusted to meet the hatchery's goals. Management strategies are developed each year based upon the specific cost-recovery and broodstock requirements, the forecast returns, and other factors as appropriate. These management strategies are formalized annually for each hatchery in the AMP (Prince William Sound - Copper River RPT 1994).

Mixed-Stock Fisheries

In Alaska, the ocean-ranching program has complicated management since its inception by the intermingling of hatchery and wild fish in the common property fishery. The regions where this has become a major concern are Kodiak, Cook Inlet, Prince William Sound, and Southeast (Krasnowski 1997). The mixed-stock fishery has apparently recently reduced some wild stocks below desirable numbers as evidenced by low wild pink salmon returns to the Coghill District in northwest Prince William Sound (Smoker et al. 1999). A few wild stocks of chum salmon in Southeast Alaska have probably experienced some detrimental effects of large-scale enhancement efforts, and at least one (Sheep Creek) may have been extirpated (Halupka et al. 2000).

The concern of overexploitation of wild fish can be amplified by the geographic location of hatcheries and release sites. For example, the Neets Bay and Whitman Lake hatcheries in Southeast Alaska are located along the migration pathway of numerous wild Behm Canal stocks (Halupka et al. 2000). The sustainability of high exploitation rates for southern Southeast Alaska and Lynn Canal coho and chum salmon is a concern. Declines in the early-run coho salmon in the Skeena and Taku Rivers may be caused by overharvest in the fishery directed at sockeye salmon. A similar concern exists for late-run coho salmon from Lynn Canal that are harvested in a fishery directed at chum salmon runs to the Chilkat River (Halupka et al. 2000). Wild coho salmon returning to Salmon Lake are of special concern due to increased fishing pressure targeting hatchery-produced (Medvejie) chum and coho salmon in the Deep Inlet SHA (Schmidt 1996).

Attempts to reduce risks to wild stocks from overharvest have been implemented by siting facilities where harvests are not mixed (e.g., Hidden Falls) and by using tags to identify hatchery fish in mixed harvests (e.g., Nakat Inlet). In areas of mixed-stock fisheries, large-scale marking programs (thermal otolith marks) have been initiated to contain the risk (Smoker et al. 1999).

Escapement

Wild Stocks. In order to achieve biological escapement goals (BEG) to ensure maximum sustained yield, managers depend upon in-season assessment of relative annual abundance. BEGs have been formulated by ADF&G for salmon by major river system. The in-season assessment is accomplished by using numerous methods including catch data from ongoing fisheries, test fisheries, aerial surveys, and weirs. The effectiveness of in-season management is evaluated by spawning escapements and exploitation rate estimates for indicator stocks. To monitor escapements ADF&G uses weirs, aerial surveys, towers, sonar, mark-recapture studies, and ground counts of spawners or carcasses on index streams. The methods may vary from region to region. Escapement goals for Alaska streams were established in the 1960s and 1970s and revised in 1991 for Prince William Sound, Cook Inlet, and Bristol Bay (Fried 1994). In Prince William Sound, for example, there are over 800 pink salmon streams. ADF&G seasonally monitors between 150 and 200 of these (which serve as the index streams) with weekly aerial surveys. ADF&G also enumerates escapements of two major sockeye systems in Prince William Sound by daily weir counts. Escapement was met for all index streams between 1990 and 2000 except in 1992, a year with very low returns in Prince William Sound for all stocks (Sharp et al. 2000).

In Southeast Alaska, there are over 5,000 streams producing anadromous fish. About 3,000 of these are principal salmon-producing streams and coho, pink, and chum salmon are found in most all of them. Most escapement estimates in Southeast are done by aerial survey along with some weir data and mark-recapture estimates. Escapement trends for coho salmon are primarily monitored for 34 streams in six stock groups (Yakutat, Lynn Canal, North-Central, Taku, Stephens Passage, Southern Inside), and none of these streams showed declining trends in escapement between 1981 and 1996 (Van Alen 2000). Helicopter surveys and weirs are used to count chinook escapements at 27 locations in 11 river systems. ADF&G is in the process of developing new spawner-recruit (S-R) escapement goals for chinook in Southeast to replace those established prior to 1985. New S-R escapement goals have been established for six systems (Situk, Alsek, Unuk, Chickamin, Blossom, Keta), and chinook escapements to these six systems have generally been within or above goal ranges since 1981 (Van Alen 2000). Reliable indices, or estimates, of annual escapements are available for just a handful of the over 200 systems in Southeast that produce sockeye salmon. Total run size is estimated for nine systems primarily using weir counts with mark-recapture studies as backup. Two systems (Chilkoot and Italio) have shown a downward trend in sockeye escapement counts over the 1980 to 1996 period (Van Alen 2000).

Since 1960, ADF&G has intensively monitored pink salmon escapements in 1,588 Southeast streams, but usually fewer than half are surveyed in any given year. Most counts are by aircraft and foot with occasionally counts by helicopter, weirs, or mark-recapture studies. Escapement trends were estimated using peak aerial survey counts from 652 streams between 1960 and 1996. Overall, escapement indices showed an upward trend for both northern and southern Southeast Alaska pink stocks. Florence Creek (Admiralty Island) was the only one of the 652 index streams to show a significant downward escapement trend (Van Alen 2000). ADF&G does not have a standardized program for indexing the escapement of chum salmon in Southeast, but aerial and foot escapement survey counts dating back to 1960 are available in its database. Baker et al. (1996) evaluated escapement trends for 45 chum salmon stocks and found declining escapements in 10. A decline in escapements of Chilkat River chum salmon has been an ADF&G concern since the mid-1980s (Van Alen 2000).

There are approximately 800 streams on Kodiak Island where salmon have been documented. Of these, 4 support chinook, 39 support sockeye, 150 support chum, 174 support coho, and all support pink salmon. The majority of sockeye and all chinook salmon escapement counts are obtained from weirs that are located on 12 spawning systems. Some pink, chum, and coho salmon escapement counts are also obtained from weirs, but most come from aerial surveys. Since the 1980s, the BEG has been met or exceeded for chinook, sockeye, pink, and coho salmon on Kodiak Island. Chum salmon production has been variable and low since 1992, nevertheless, the BEG has been achieved in 9 of 10 years between 1988 and 1998 (Prokopowich 2000).

There are approximately 582 documented spawning streams within the Alaskan Peninsula and Aleutian Islands. Most salmon escapement estimates are derived from aerial surveys plus five weirs that are used for monitoring sockeye salmon. Escapement estimates for the area are indexed totals and are limited to chinook, sockeye, pink, and chum salmon. Since 1989, average indexed total escapements have been above the escapement goal range for all species (Shaul and Dinnocenzo 2000). The Chignik River on the Alaskan Peninsula is in a separate management area and is monitored by a weir. Chinook and sockeye salmon escapements were above the BEG in 1997.

In general, Upper Cook Inlet salmon stocks are in good condition insofar as assessments of spawning escapements have been conducted. The best assessments are sonar counts of sockeye entering the larger watersheds (Kasilof, Kenai, Crescent, Susitna), followed by weirs. The majority of salmon spawning localities in Upper Cook Inlet have no direct assessment of escapements. The overall return of sockeye salmon in 1998 was low. Since the late 1980s, the Crescent River sockeye salmon run has declined and ADF&G is reducing the BEG for this system to reflect a decreased capability of the system to rear fish. Recent returns of sockeye to Fish Creek in Knik Arm have been poor and in 1998 produced less than 50% of the desired escapement. Chum salmon production has been relatively poor in recent years for the Susitna Basin. Coho stocks have generally produced strong runs throughout the 1980s and 1990s except for 1997, which was a substandard year in most drainages. After experiencing a significant downturn in the early 1990s, chinook salmon escapements continue to trend upward (Ruesch and Fox 1999).

In Bristol Bay, several indicators of run size are used including the False Pass fishery, Port Moller test fishery, tower counts, sonar, and aerial surveys. Sockeye salmon dominate the fishery in Bristol Bay and spawning escapement requirements have been defined by ADF&G for eight river systems there (Naknek, Kvichak, Egegik, Ugashik, Nushagak, Togiak, Wood, Igushik). Sockeye escapement goals were met or exceeded in all of these systems in 1999. Two of these systems (Kvichak and Nushagak) had difficulty meeting escapement goals for the 10-year period from 1989 to 1998. The 10-year escapement average for the Kvichak system was 12% below the goal (ADF&G 2000).

The vast size and remoteness of the Kuskokwim, Yukon, and Norton Sound areas present challenges to monitoring salmon escapements. Aerial spawning surveys have been the principal means of monitoring salmon escapements but over the past few years the use of weirs, counting towers, and sonar operations has increased. Most of the BEGs for these areas are based on average annual escapements from aerial surveys. Many of these are being reviewed and modified. Seven projects using weirs, counting towers, or sonar were operated in the

Kuskokwim area in 1999 to better monitor escapement. Escapement at the Kogrukluk River weir in 1999 was just over half of the BEG for chinook, under 50% for coho, and 54% for chum salmon (Burkey et al. 2000).

Most monitoring in the Yukon Drainage is for chum or chinook salmon and includes sonar (hydroacoustic), ground surveys, counting towers, and mark-recapture projects. Chinook salmon minimum escapement goals were generally achieved in the Alaskan, but not the Canadian portion, of the Yukon Drainage in 1999. The 1999 run was larger than the very weak 1998 run but below that of 1997. Escapements of summer chum in the Anvik River, the largest producer of summer chum in the Yukon Drainage, were above the escapement goal from 1991 to 1997. In 1998 no escapements in monitored tributaries met escapement goals and ranged from 27% to 81% below average. In 1999 the summer chum run in the Anvik was 12% below the minimum escapement goal. The 1998 and 1999 fall chum runs into the Yukon River were 46% and 44% of normal run size expectations. With the exception of the upper Tanana River, spawning escapements were below average but still within minimum escapement goals. In the Toklat River (Tanana Drainage), the 1999 escapement estimate was 86% below the minimum escapement goal and the lowest on record since 1982 (Bergstom et al. 2001).

Escapement projects in Norton Sound include counting towers on seven rivers, a test net on the Unalakleet River, and a weir on the Nome River. Overall, in 1998 returns of chinook salmon were average to above average, coho salmon were average to below average, and chum salmon were below average. Several streams in the northwest area (Pilgrim, Sinuk, and Nome) had chum escapements below goal. Escapement indices for Shaktoolik and Unalakleet were also below escapement goals in 1998 (Brennan et al. 1999). Also of concern in the Nome area was the fact that no chum salmon returned to the Penny and Cripple Rivers in recent years, causing concern for the extirpation of these populations (Clark 2000).

A recent review of salmon escapement data and estimation methods in western Alaska was conducted by a group of scientists who were asked by the commissioner of ADF&G to assist the Alaska Board of Fisheries (Independent Scientific Review Committee 2001). The group concluded "…the basic data on stock and recruitment are not as precise as would be desirable." Of particular concern was the general inability in many instances to allocate catches to river of origin, which precluded keeping track of trends in productivity by river system.

Hatchery Stocks. Ideally, one does not want escapement of hatchery fish but sufficient returns to the facility for the purpose of cost recovery and broodstock use. In most years, this is what takes place at PNP hatcheries. Occasionally, especially during broodstock development, there have been insufficient returns or a hatchery has harvested into its broodstock and not ended up with enough eggs. There have also been a few instances when too many fish returned and hatchery fish spilled over into adjacent streams and beaches. In 1998 a huge return of pink salmon in Prince William Sound flooded the processors and an unknown number went unharvested. In 1996 a large chum salmon return went underharvested in Southeast and many dead chums were noted on beaches. When this happens, there is a greater potential for hatchery fish to migrate to nearby streams and spawn with wild stocks. This is an undesirable scenario and ADF&G will take appropriate action including adjusting fishery openings or modifying hatchery permits to rectify the situation.

Discriminating Hatchery Fish in the Harvest

Understanding the relative impact of fisheries on wild stocks requires knowing what proportion of the harvest is of hatchery origin. This is akin to the need for managers to know the origin of wild salmon by watershed in order to track trends in productivity and to set escapement goals. Recognizing hatchery fish in the harvest has recently become much easier due to advances in mass tagging technologies.

The first major breakthrough in distinguishing between large numbers of hatchery and wild fish came with the use of coded-wire tags (Riffe and Evans 1998; Sharr et al. 1996). Coded-wire tags allowed reasonably precise estimates of the proportion of hatchery salmon in each harvest by the end of the season. However, its use for in-season management was limited by technical difficulties that have since been solved by thermal mass-marking. Thermal marking of otoliths was initiated in Prince William Sound in 1995, and since 1997 all hatcheries there are so marking released fish. This tool has greatly increased ADF&G's ability to manage the fishery, for within 24 hours managers can determine what percent of the catch is hatchery and to a degree of precision not possible with the previous marking technology. This information gives managers the basis for opening, closing, or otherwise modifying the fishery to control the proportion of wild salmon in catches to ensure wild salmon escapement. Since 1997, all escapement goals in Prince William Sound have been met or exceeded and the thermal-marking tool is likely responsible for this success.

In Southeast Alaska, it is felt that better segregation of the chum salmon runs has made the fishery easier to manage than in Prince William Sound; nevertheless, ADF&G is encouraging all hatcheries to thermally mark all chum salmon (S. McGee, pers. comm.). Currently, most Southeast hatcheries are thermally marking chum and sockeye salmon and all pink salmon are marked at the Gastineau hatcheries. Northern Southeast and Douglas Island PNPs have been doing so since 1997, and the Southern Southeast Regional Aquaculture Association is in the process of implementing structural changes to its facilities that will enable marking 100% of released chum salmon. Some smaller operations, like the Gunnuk Creek hatchery, have not yet been able to comply with this request due to complex water quality and allocation problems. Due to ongoing research projects and complex U.S.-Canada treaty considerations, coded-wire tagging operations are still used for chinook and coho salmon marking.

CONCLUSIONS

There has been little systematic evaluation of the effects of hatcheries on natural systems. Most evaluations of hatcheries are economic rather than biologic, as might be expected given the commercial purpose of large-scale hatchery production. Another commonly recognized benefit from hatcheries is stocking with trout and salmon throughout the United States for sport fisheries. The most common and accepted biological benefits attributed to hatcheries are their use for research and as possible refuges for threatened or endangered species. Critics of hatcheries often do not agree among themselves on the nature and severity of the risks hatcheries pose or on ways to minimize them (Waples 1999). Various scientific reports have asserted that hatchery-produced salmon stocks have reduced or replaced wild stocks (Eggers et al. 1991; Hilborn and Eggers 2000), while others offer differing views (Smoker and Linley 1997; Wertheimer et al. 2001). Some argue that genetic diversity can be reduced by artificial propagation (Reisenbichler and Rubin 1999), others diminish the risk (Campton 1995), and others minimize it (Cuenco 1994). Given these divergent views and the lack of data that prove any one view, research is needed to shed light on the issues and hopefully provide practical solutions.

Alaska's ocean-ranching salmon hatcheries operate amidst considerable uncertainty. Perhaps the most striking feature in conducting this review was encountering so many gaps in the available scientific data from which one can fairly draw conclusions on the effects hatcheries may or may not have on wild salmon. Alaska has been successful in augmenting salmon harvest, but in accomplishing this, the question of whether salmon biodiversity has been adequately protected is unanswered. The robust and reliable data necessary to evaluate interactions between hatchery and wild salmon populations have not, in most cases, been collected. Decisions regarding the efficacy of hatcheries or ocean ranching should be based on sound science. Unfortunately, due to uncertainties and gaps in the available data, management decisions are more often based on short time frames and focused on local concerns rather than on long-term time frames and whole ecosystems. Better data are needed to bring consensus among scientists and managers on how to figure uncertainties, such as ocean carrying capacity and genetic risk to wild fish from hatchery straying, into the complex management equations. Until such data are available and algorithms for using them developed, the prudent course for management is a conservative one.

In the comprehensive salmon plan for Prince William Sound, one of the recommendations is that the proportion of hatchery salmon straying into wild stock streams must remain below 2% of the wild-stock escapement over the long term (Prince William Sound - Copper River RPT 1994). This recommendation is obviously not being followed. Straying of hatchery fish in Prince William Sound and Southeast is a major concern that is not being adequately addressed and needs to be brought fully into the light. Without proper monitoring, it cannot be said with certainty what impact high hatchery straying rates are having on wild fish. Potentially it is of significant magnitude and may not be in line with Alaska's Sustainable Salmon Fisheries, Finfish Genetics, and Salmon Escapement Goal Policies, or with the wild stock priority statute as it relates to the protection of wild stocks.

After more than 30 years of debate about the impact of hatchery fish on the genetic diversity of wild salmon populations, there still is no definitive answer to this concern (even given the increase in the body of knowledge). It may be easy to identify risks that hatcheries pose for natural populations; it is not so easy to predict whether deleterious effects have occurred or, if they have, how serious the consequences will be. One problem with genetics research is that it can be costly and lengthy. Regardless, it is prudent to continue investigations in this area. Given the documented incidence of straying of hatchery fish, especially pink and chum salmon in Prince William Sound and Southeast Alaska, an increased commitment to genetic studies and monitoring of wild stocks proximal to hatcheries for any detectable genetic changes is warranted. Elucidation of salmon population structure is always important information for developing management programs designed to conserve biologic and genetic diversity.

Is Alaska's Finfish Genetics Policy sufficient to protect the state's wild salmon? Protection of wild stocks is a principal objective of the policy, which is considered to be one of the more conservative policies in the country (Davis and Burkett 1989). That said, the policy has not been revised since 1985 and could be updated to ensure that the most recent molecular genetic knowledge and technologies are used. There are examples of hatchery practices that are out of compliance with this policy and accepted practices elsewhere. The policy calls for a single donor stock to be used in no more than three hatcheries. Five Andrew Creek chinook and four Sashin Creek coho stocks have been used at Southeast hatcheries. It is difficult to follow the trail of chum salmon hatchery stocks in Southeast, but it appears that the Hidden Falls hatchery is made up of at least three separate stocks that in turn have been used (albeit to a limited extent) in four other hatcheries. The restriction on stock transport to within regions sounds good, but Southeast Alaska is a big region and stocks are transported over large distances. It is a recommended practice in other parts of the country and in Canada to occasionally infuse wild gametes into a hatchery population for conservation purposes. This is currently not being done in Alaska, although most hatcheries have outbred their broodstocks in one way or another, either from the inclusion of strays (e.g. Prince William Sound pinks) or from wild stock egg take programs (e.g. Gastineau coho, Neets Bay coho).

The Finfish Genetics Policy came about as a result of a concern that the development and operation of a hatchery system could, if not done properly, have a detrimental impact on wild salmon populations. A provisional policy was developed in 1975 and the most current revision was published in 1985. The policy contains guidelines that provide for the application of genetic principles to the development and management of hatchery broodstock. ADF&G applied the existing body of population genetics knowledge to the development of the Finfish Genetics Policy, but at that time there was little, if any, information on genetic impacts of hatchery-produced fish on wild populations.

The need to conserve genetic information is fundamental to salmon biodiversity conservation. Both commercial fishing and hatchery production can adversely affect conservation of genetic diversity. The Finfish Genetics Policy recommends designation of hydrological basins or geographic areas as gene preserves—perpetual repositories of genetic information for all plant and animal species inhabiting such areas. Currently, there are no officially recognized gene preserves in Alaska specifically established for salmon species. This issue has been examined by several of the RPTs. For example, the Cook Inlet RPT considered several streams on the Kenai Peninsula in the early 1990s as stock reserves or gene preserves for one or more salmon species. Unfortunately, this process was not completed due to funding constraints (G. Fandrei, pers. comm.). This is an oversight of long standing and should be addressed.

Another example of where a well-informed genetics policy is essential can be seen in evaluating hatchery-siting criteria. The majority of PNP hatcheries were permitted prior to 1992; the two large hatcheries in western Prince William Sound were permitted in 1975 and 1983. Most Alaska hatcheries were sited with land ownership and water quality as preeminent criteria, with less attention given to biologic concerns. Considerable biologic and managerial knowledge has accumulated since these hatchery sites were permitted. Many state hatcheries are located in areas that make straying into wild stock waters and complicated mixed-stock fisheries management inevitable. Both RPTs and the Finfish Genetics Policy address hatchery siting. In view of the mandate to protect wild stocks, the hatcheries in western Prince William Sound (as well as others, especially some in Southeast) may be less than ideally sited with regard to wild-hatchery interaction.

The question is often asked: To what extent are wild salmon stocks overexploited in mixed-stock fisheries? Management of a mixed-stock fishery is a complex problem even without hatcheries. Factoring hatchery fish into the management equation only makes a hard job more difficult. It is important not to overharvest small salmon populations that may contain unique adaptive traits (and genes). Given the number of streams in Alaska (and corresponding number of salmon stocks) coupled with the size of the ADF&G staff and state budget, conducting the monitoring required to ensure that no wild salmon stocks are being negatively impacted by overfishing or invasion of hatchery strays is nearly impossible. In Prince William Sound alone, ADF&G currently monitors 150 to 200 of the approximate 800 streams found there for escapement. In order to monitor all 800, a much larger staff and logistics budget would be needed. The advent of thermal marking is a significant advance in technology that will enable a much closer and more thorough monitoring of mixed-stock fisheries and subsequently better protection of wild stocks. Hatcheries are moving in the direction of marking all released fish, which will improve mixed-stock management.

Management of fisheries and of hatcheries must be integrated and adaptive. There is a need to change the expectations of managers and harvesters to coincide with the natural variation and uncertainty in the abundance of salmon populations (Knudson 2000). More reliable and timely estimates of wild-stock escapements and run sizes are needed to direct management of the mixed-stock fisheries, especially for those that harvest chum salmon in Southeast Alaska.

There is significant concern over competition for resources between hatchery and wild salmon stocks. Based on a review of the scientific literature and discussions with biologists, geneticists, and fishery managers about protecting salmon biodiversity, the potential impacts of extensive ocean ranching appear to pose a great concern for the ocean's carrying capacity. This may become the most important issue for assessing risks to wild salmon populations, especially for those with comparatively small numbers of individuals. It will likely become a higher risk than loss or change in genetic diversity due to hatchery practices. It has been hypothesized that hatchery-produced chum salmon from Southeast Alaska may be having a negative impact on wild stocks of chum salmon in Western Alaska through density-dependent interactions like competition for food in the marine environment. ADF&G believes that there is no conclusive evidence to link hatchery production in one part of Alaska with declines of wild salmon in another and, in fact, has seen indications of the opposite for chum salmon, where survival of both wild and hatchery chum salmon are high in Southeast Alaska (although this may not be true for fall run chums in Lynn Canal). Nevertheless, there is evidence (smaller size, soft flesh) that Asian salmon have suffered deleterious effects leading some researchers to conclude that the carrying capacity of the western North Pacific for pink and chum salmon has been exceeded. It is also thought that high numbers of pink salmon (many of them hatchery derived) may lead to lower numbers of chum salmon.

Environmental conditions favorable for producing salmon are (and have been for several years) on a decline in the northern portion of the North Pacific. Consistent with this are results of several studies indicating declines in the size of harvested salmon. Although increased competition may not lead directly to increased mortality, wild fish that survive to spawn may have fewer eggs, less energy to reach spawning grounds, and smaller bodies to contribute to the ecosystem. According to Myers et al. (2000), underlying mechanisms of the processes linking climate, ocean productivity, and salmon production are not well understood and better information is needed on salmon distribution, abundance, and migration patterns with respect to environmental conditions.

The potential for hatchery-bred salmon to displace wild fish in the ocean, coupled with the lack of knowledge about complex dynamics of the North Pacific ecosystem as a whole, suggests that it would be prudent to manage Alaska's hatcheries conservatively. In other words, it would be better to reduce the state's hatchery release numbers in years of lower ocean-productivity indices. This would comply with Alaska's Sustainable Salmon Fisheries Policy requirement to manage in accordance with the precautionary principle (manage conservatively). The state's PNP hatcheries have reached a plateau of about 1.4 billion fish released into the marine environment and since 1997 have had about 150 million pink and 200 million chum salmon egg take removed from their permits. Given the various concerns and indicators that ocean carrying capacity for salmon in the northern North Pacific is likely on a decline, the number of hatchery releases may still be high (especially for pink and chum salmon in Prince William Sound and Southeast, respectively) and may be contrary to the Sustainable Salmon Fisheries Policy.

There is a need for greater scientific and public understanding of the climatic influences on fisheries and aquatic resources. Aquatic ecosystems are vulnerable to a range of climate change impacts including temperature changes, altered stream flows and ocean patterns, reduced water quality, and coastal changes. Addressing these impacts has not yet become a priority for scientists, as well as policymakers. It is incumbent upon scientists to determine which physical and biological processes lead to changes in salmon growth and survival so that when the ocean enters a different climate regime, the role ocean conditions play in changing trends of fish growth or survival can be ascertained (Brodeur et al. 2000).

With respect to fish-culture practices themselves, Alaska's hatchery practices as a whole are among the best in North America. The main reasons for this are both fortuitous and purposeful. By choosing to concentrate on pink and chum salmon, Alaska's ocean-ranching program has avoided many of the attenuated problems (e.g. domestication and ecological) with long-term rearing species like steelhead trout and coho salmon. Given the late date at which Alaska's ocean-ranching program was established, the state benefited from mistakes that had been made elsewhere and got the program started on better footing by having genetic oversight of operations through fish transport permits, hatchery siting, egg takes, broodstock development, etc. Oversight of fish diseases by the state's pathology department has been exemplary and closely follows the Fish and Shellfish Health and Disease Control Policy.

Given the concerns surrounding the biologic and management issues of ocean ranching, prioritizing research objectives can help narrow existing information gaps. Evaluation of hatchery operations have been inadequate. The State of Alaska has a rigorous permit procedure for starting a hatchery, outstanding pathology guidelines, and a good genetics policy. These tools are all very good in getting a hatchery properly started. However, hatcheries do not face sufficient supervision, monitoring, or evaluation once they are operating. As can be seen by perusing the reports or plans currently available, it is difficult if not impossible to gauge whether hatchery programs are impacting wild stocks or not. Hatchery programs should be evaluated rigorously on an ongoing basis by independent teams of scientists to determine whether they are achieving their goals and are not compromising other worthy goals.

Monitoring of hatchery practices is a duty and responsibility of the RPTs. Judging from the type of reports they produce (e.g. AMPs), their primary concern is development of hatchery-production plans and evaluating the resulting contribution to the fisheries. There is extensive documentation regarding egg takes, incubation, rearing, and broodstock, as well as regarding management of fisheries on hatchery returns including common property fisheries, SHAs, cost recovery, and marking/tagging studies. However, there is virtually no information about whether egg takes reflect the run-timing characteristics of the stock; the degree to which adequate numbers of spawners are used for hatchery broodstock; how often a stock has been used as a brood source; straying rates; or the number and final destination of fish that escaped the cost-recovery harvest. There is some information in certain plans that addresses the protection of wild stocks, but there is almost no information on how effective any of the proposed measures have been. As to whether a hatchery site is appropriate (one of the public benefit criteria), no published documentation addressing this point was found.

In recent years, several research initiatives have been suggested that are germane to the ocean-ranching issue. The Sound Science Review Team (1999) prioritized information needs regarding fishery ecosystems, focusing on Prince William Sound, and highlighted the need to evaluate interactions between hatchery and wild salmon. The reviewers identified three areas of concern: conservation, ecology, and management and suggested 18 specific research objectives (see Appendix B). As the present evaluation of biologic and management issues relating to ocean-ranching has made clear, there is insufficient data to ascertain the consequences of interactions between wild and hatchery-produced salmon. Unresolved questions involve a range of topics: fish culture, genetics, ecological interactions, competition between hatchery and wild salmon, and climatic change. Further, how all these factors affect salmon productivity is puzzling and deserves the attention of scientists and managers alike. Alaska's Sustainable Salmon Fisheries Policy mandates that, in light of uncertainty, a precautionary approach to management will best ensure the long-term protection of salmon biodiversity. Protection of biodiversity is the best insurance policy for survival of Pacific salmon, especially in the event of significant future environmental change.

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GLOSSARY

Adaptation. Evolutionary process resulting in an organism becoming optimally suited to its environment.

Aleutian Low. A winter weather pattern over the North Pacific that influences ocean productivity.

Allele. One of two or more alternate forms of a gene or other segment of DNA.

Anadromous. Fish that migrate from freshwater spawning areas to ocean waters and return to freshwater to spawn.

Aquaculture. The cultivation of fish or shellfish for food.

Artificial propagation. Any fish-culturing activity involving modification of natural spawning, incubation, or rearing habitat.

Biodiversity. Variety and variability among living organisms and the ecological complexes in which they occur at many biological levels, ranging from genes to species to ecosystems.

Broodstock. Adult fish retained for artificial propagation.

Carrying capacity. The maximum number or biomass of organisms that can be supported by a given habitat over the long term.

Conspecific. Belonging to the same species.

Deoxyribonucleic acid (DNA). Molecule that contains the genetic code consisting of a sequence of nucleotides.

Ecosystem. A community of organisms and their environment forming an interrelated unit.

Effective population size *(Ne).* Size of an ideal population that would have the same rate of increase in inbreeding or decrease in genetic diversity by genetic drift as the population being studied.

Electrophoresis. Technique for separating molecules based on their different mobility in an electric field.

Endemic. Refers to an organism that is either indigenous in or restricted to a specific geographic locality.

Fitness. Relative survival value and reproductive capability of a given genotype in comparison with others of a population.

Fry. Juvenile salmon at the time of yolk absorption and initiation of active feeding.

Gene. Basic unit of inheritance transmitted as part of the chromosome.

Gene flow. Exchange of genes (in one or both directions) between populations.

Gene pool. Sum total of genes in a breeding population.

Genetic diversity. Totality of genetic information that exists in a stock.

Genetic drift. Variation of allele frequency from one generation to the next due to chance fluctuations.

Genetic integrity. Population genetic structure in an unimpaired or sound condition.

Genotype. Genetic identity of an individual.

Hatchery fish. Any fish resulting from artificial spawning and rearing regardless of the history of the parent stock.

Hybridization. A cross between two genetically dissimilar individuals resulting in hybrid offspring.

Inbreeding. Mating of related individuals.

Inbreeding depression. Permanent or temporary reduction in fitness due to inbreeding.

Introgression. The incorporation of genes from one species or distinct population into the gene pool of another.

Linkage. Genes are linked when they are transmitted as pairs or sets because they are located close together on a chromosome.

Migration. Movement of any number of individuals or populations from one geographic location to another.

Mixed-stock fishery. A fishery where more than one stock of fish is harvested simultaneously.

Native. Fish stocks or populations indigenous to an area resulting from natural spawning.

Natural selection. Natural process by which organisms leave differentially more/less descendents than other individuals because they possess certain inherited advantages/disadvantages.

Ocean ranching. The process of artificially hatching and releasing juvenile fish into the ocean with the intent of later harvest as adults.

Otolith. Ear bone in fish that can be sectioned for the purpose of aging and can be imprinted with characteristic markings by modulating water temperature during culture for later use in identifying fish from a particular hatchery.

Outbreeding. Mating pattern in which mating between close relatives does not usually occur.

Outbreeding depression. Decrease in fitness resulting from hybridization between distant, isolated populations.

Parr. The freshwater stage of juvenile salmon between fry and smolt.

Pacific Decadal Oscillation (PDO). A pan-Pacific, recurring pattern of ocean-atmosphere variability that alternates between climate regimes every 20 to 30 years.

Phenotype. Visible properties of an individual produced by the interaction of the genotype and the environment.

Population. Group of organisms of the same species that occupy a well-defined locality and exhibit reproductive continuity from generation to generation.

Regime. A multiyear period of linked recruitment patterns in fish populations.

Run. Seasonal migration upriver to spawn.

Selection. Process (either natural or artificial) whereby select individuals, based either on fitness or other predetermined criteria, serve as broodstock for the next generation.

Smolt. Juvenile salmon at time of physiological adaptation to life in saltwater.

Special harvest area. An area, designated by the commissioner or the Board of Fisheries, where hatchery returns are to be harvested by the hatchery operators, and in some situations, by the common property fishery.

Species. Group of individuals that can interbreed successfully with one another but not with members of other groups.

Stock. Population sharing a common environment and participating in a common gene pool that is sufficiently discrete to warrant consideration as a self-perpetuating system, which can be managed.

Strain. Group of individuals coming from a particular location or produced by a particular breeding program.

Straying. The behavior of returning to a location other than the location of origin.

Terminal harvest area. An area where hatchery returns have achieved a reasonable degree of segregation from naturally-occurring stocks and may be harvested in the common property fishery without overharvesting wild stocks.

Translocation. Moving an individual or progeny from individuals outside its indigenous geographic range.

Wild (naturally-produced) fish. Fish or stock naturally spawned and reared.

APPENDIX A

BROODSTOCK HISTORY
(Adapted from various ADF&G files)

Table A1. Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: NSRAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: HIDDEN FALLS					
Chum	Kadashan River	77–80	Same region	Kasnyku Bay	
	Clear River	78–79	Same region	Kasnyku Bay	
	Seal Bay	80–81	Same region	Kasnyku Bay	
	Hidden Falls	81–99	proximate	Kasnyku Bay, Baranof Bay, Takatz Bay	
Coho	Deep Cove	88–90	SE/nearby district	Kasnyku Bay	
	Sashin Creek	89–93	SE/nearby district	Kasnyku Bay	
	Hidden Falls	91–98	proximate	Kasnyku Bay	
Chinook	Andrew Creek	81–88	SE/nearby district	Kasnyku Bay	
	Tahini River	83–91	SE/nearby district	Kasnyku Bay, Lutak Inlet	
	Crystal Creek	85–91	SE/nearby district	Indian River, Eliza Lake, Kasnyku Bay	Hatchery stock/Andrew Creek
	Farragut River	89–90		Farragut Lake	
	Medvejie	90–93	SE/nearby district	Kasnyku Bay	Hatchery stock/Andrew Creek
	Hidden Falls	90–99	proximate	Taiya Inlet, Kasnyku Bay, Indian River	
LOCATION: MEDVEJIE CREEK					
Chum	Medvejie Creek	81–99	proximate	Deep Inlet, Bear Cove	
	Nakwasina River	82–84	SE/same district	Deep Inlet	
	Salmon Lake	82–85	SE/same district	Deep Inlet	
	Deep Inlet	85–91	proximate		
	Hidden Falls	89–99	SE/same district	Deep Inlet	

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: NSRAA cont.					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: MEDVEJIE CREEK cont.					
Coho	Sealion Cove	81–84	SE/same district		Broodstock for lake stocking
	Sashin Creek	81–99	SE/nearby district	Deer Lake	Broodstock for lake stocking
	Deep Cove	81–97	SE/nearby district	Banner Lake	Broodstock for lake stocking
	Falls Creek	82–84	SE/same district	Elfendahl Lake	Broodstock for lake stocking
	Indian River	88–98	SE/same district	Deep Inlet, Bear Cove, Shamrock Bay	
	Medvejie	91–97	proximate	Bear Cove, Shamrock Bay, Wrinkleneck Creek	
	Hidden Falls	93–97	SE/nearby district	Deer Lake	Hatchery stock/Sashin Creek
Chinook	Andrew Creek	82–83	SE/nearby district	Bear Cove	
	Crystal Lake	84–94	SE/nearby district	Bear Cove	Hatchery stock/Andrew Creek
	Medvejie	86–99	proximate	Bear Cove	Current primary source
	Little Port Walter	88–89	SE/nearby district	Bear Cove	Hatchery stock/Chickamin River
	Ohmer Creek	89	SE/nearby district	Bear Cove	
	Whitman Lake	89–90	SE/nearby district	Bear Cove	Hatchery stock/Chickamin River
	Hidden Falls	94–96	SE/nearby district	Bear Cove	Hatchery stock/Andrew Creek
LOCATION: HAINES					
Chum	Slough	84–93	proximate	31 Mile Creek	Incubation boxes
	Spawning Channel	90–97	proximate	17 Mile	Spawning channel
	Herman Creek	94–99	proximate	Herman Creek, 17 Mile, 31 Mile	
	31 Mile Incubator	98–99	proximate		
Sockeye	Spring Pond	90–98		Chilkat Lake	
	Garrison Creek	95		Garrison Creek	
	Chilkat Lake	97		Chilkat Lake	

OPERATOR: SSRAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: WHITMAN LAKE					
Chum	Carroll River	79–97	Same region	Nakat Inlet, Earl West Cove, Kendrick Bay	Summer chum
	Cholmondelay	86–92	Same region	Nakat Inlet, Earl West Cove, Kendrick Bay	Fall chum
	Disappearance Creek	80–94	Same region	Neets Bay, Nakat Inlet	
	Nakat Inlet	82–86	Same region	Nakat Inlet	
	Burnett Inlet	90	Same region	Earl West Cove	Hatchery stock
	Neets Bay	98–99		Nakat Inlet, Earl West Cove, Kendrick Bay	Summer chum

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: SSRAA cont.					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: WHITMAN LAKE cont.					
Coho	Indian Creek	78–82	SE/same district	Herring Cove, Neets Bay	
	Whitman Lake	81–98	proximate	Herring Cove, Nakat Inlet, Earl West Cove	
	Karta River	95–96	SE/nearby district	Old Frank Lakes	
	Ward Lake	95–97	SE/same district	Herring Cove, Neck Lake	
Chinook	Unuk River	80–90	SE/nearby district	Herring Cove, Neets Bay, Carroll Inlet	
	Chickamin River	81–99	SE/same district	Carroll Inlet, Herring Cove	
LOCATION: NEETS BAY					
Chum	Carroll River	83–97	Same region	Neets Bay, Kendrick Bay	Summer chum
	Cholmondelay	84–97	Same region	Neets Bay, Nakat Inlet	Fall chum
	Disappearance Creek	89–94	Same region	Neets Bay	
	Neets Bay	98–99	proximate		
Coho	Neets Bay	81–90	proximate		
	Whitman Lake	89–98	SE/same district	Neets Bay	Hatchery stock/Indian Creek
Chinook	Ketchikan Creek	83–99	SE/same district	Neets Bay	Hatchery stock/Unuk River
	Whitman Lake	91–99	SE/same district	Neets Bay	Hatchery stock/Chickamin River
LOCATION: BURNETT INLET					
Coho	Big Creek	84–88	SE/same district	Burnett Inlet	
	Burnett Inlet	87–92	proximate		
	Ketchikan Creek	96–98	SE/nearby district	Burnett Inlet	Hatchery stock/Reflection Lake
Sockeye	Hugh Smith Lake	98–99	Hugh Smith Lake		

OPERATOR: AKI					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: PORT ARMSTRONG					
Pink	Sashin Creek	83–96	Same region	Port Armstrong	
	Port Armstrong	85–99	proximate		
Coho	Blanchard Lake	88–90	SE/same district	Jetty Creek	
	Deer Lake	89–92	SE/same district	Jetty Creek	Hatchery stock/Sashin Creek
	Port Armstrong	91–98	proximate		
	Hidden Falls	93–96	SE/nearby district	Port Armstrong	

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: BCF					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: BURRO CREEK					
Pink	Sawmill Creek	80–82	Same region	Burro Creek	
	Howard Bay Creek	83–89	Same region	Burro Creek	
	Burro Creek	83–98	proximate		
	Pullen Creek	90	Same region	Burro Creek	
	Gastineau	93			Hatchery stock
Chum	Howard Bay Creek	80–88	Same region	Burro Creek	
	Burro Creek	85–98	proximate		
	Taiya River	86–88	Same region	Burro Creek	
Coho	Taiya River	86–96	SE/same district	Burro Creek	
	Pullen Creek	87–92	SE/same district	Burro Creek	
	Sheep Creek	88–90	SE/same district	Burro Creek	Hatchery stock/Montana Creek
	Burro Creek	91–97	proximate		
Chinook	Hidden Falls	90-95	SE/nearby district	Burro Creek	Hatchery stock/Tahini River
	Burro Creek	94-97	proximate		

OPERATOR: DIPAC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: GASTINEAU					
Pink	Kowee Creek	77–86	proximate		3 hatcheries along Gastineau Channel: Gastineau, Kowee and Sheep Creeks
	Sheep Creek	80–92	proximate		
	Salmon Creek	90	Same region	Gastineau	
	Kadashan River	88	Same region	Gastineau	
	Gastineau	87–98	proximate		
Chum	Kowee Creek	76–83	proximate		
	Hidden Falls	88–93	Same region	Gastineau, Boat Harbor	
	Sheep Creek	81–96	proximate		
	Gastineau	87–98	proximate	Amalga Harbor, Boat Harbor, Limestone Inlet	
Coho	Montana Creek	85–87	SE/same district	Gastineau, Sheep Creek	
	Snettisham	86–87	SE/same district		Hatchery stock/Speel Lake
	Gastineau	89–97	proximate	Gastineau, Sheep Creek	
	Sheep Creek	88–90	proximate	Gastineau, Sheep Creek	
	Steep Creek	89–97	SE/same district	Gastineau, Sheep Creek	
Chinook	Snettisham	84–92	SE/nearby district		Hatchery stock/Andrew Creek
	Crystal Lake	84–92	SE/nearby district		
	Little Port Walter	93–96	SE/nearby district		Hatchery stock/King Salmon River

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: DIPAC cont.					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: GASTINEAU cont.					
	Gastineau	95–97	proximate	Gastineau, Auke Creek, Twin Lakes, Fish Creek, Taiya Inlet	No wild stock used for broodstock since 1988. All chinook may have originated from Andrew Creek or King Salmon River
LOCATION: SNETTISHAM					
Sockeye	Speel Lake	88–98	Same region	Speel Lake, Sweetheart Lake, Speel Arm, Snettisham Inlet	
	Crescent Lake	90–95	Same region	Crescent Lake, Sweetheart Lake, Gilbert Bay	
	Chilkat Lake	93–96	Same region	Chilkat Lake	
	Snettisham	96–99	proximate	Sweetheart Lake	

OPERATOR: KNFC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: GUNNUK CREEK					
Chum	Security Bay	82–83	Same region	Gunnuk Creek, Portage Bay	
	Hidden Falls	84–88	Same region	Gunnuk Creek, Kake Sha, Southeast Cove	
	Gunnuk Creek	88–99	proximate		
Coho	Portage Creek	94–96	SE/same district	Portage Creek	

OPERATOR: SJC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: INDIAN RIVER					
Pink	Indian River	75–99	proximate		
	Starrigavan Creek	76	Same region	Indian River	
Chum	Katlian River	75	Same region	Indian River	
	Nakwasina River	76–84	Same region	Indian River	
	Sandy Creek	79–85	Same region	Indian River	
	Deep Inlet	85	Same region	Indian River	
	Indian River	80–99	proximate		
Coho	Indian River	75–98	proximate	Crescent Bay	
Chinook	Crystal Creek	84–90	SE/nearby district	Sitka Sound	Hatchery stock/Andrew Creek
	Andrew Creek	85–87	SE/nearby district	Sitka Sound	
	Indian River	89–99	proximate	Sitka Sound, Crescent Bay	

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: POWHA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: KLAWOCK					
Coho	Klawock River	78–98	proximate		
	Cable River	86–92	SE/same district	Cable River	
	Thorne River	88–92	SE/nearby district	Rio Roberts	
	Karta River	93-95	SE/nearby district	Old Frank Lakes	
Sockeye	Klawock Lake	86–99	proximate	Klawock Lake	

OPERATOR: MIC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: TAMGAS CREEK					
Chum	Tamgas Creek	93–98	proximate		BIA Hatchery
Coho	Nadzaheen Creek	78–81	SE/same district	Tamgas Harbor	
	Columbia River, WA	79–81	Washington (state)	Tamgas Harbor	
	Ketchikan Creek	80–82	SE/same district	Tamgas Harbor	
	Tamgas Creek	81–97	proximate	Tamgas Harbor, Tent Lake	
Chinook	Ketchikan Creek	82–85	SE/same district	Tamgas Creek	Hatchery stock/Unuk River
	Hybrid	85–88		Tamgas Creek	Hatchery hybrid stock/ Unuk & Chickamin Rivers
	Neets Bay	86–87	SE/same district	Tamgas Creek	Hatchery stock/Unuk River
	Unuk River	87–88	SE/same district	Tamgas Creek	
	Little Port Walter	87–89	SE/same district	Tamgas Creek	Hatchery stock/Unuk River
	Tamgas Creek	87–99	proximate	Tamgas Creek	

OPERATOR: FEDERAL					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: AUKE CREEK					
Coho	Auke Creek	78–86	proximate		
	Sashin Creek	82–85	SE/nearby district	Auke Creek	
LOCATION: LITTLE PORT WALTER					
Chinook	Carson, WA	71–73	Washington (state)	Little Port Walter	Washington state hatchery stock
	Chickamin River	76–95	SE/nearby district	Little Port Walter	
	Unuk River	76–95	SE/nearby district	Little Port Walter	
	King Salmon River	88–92	SE/nearby district	Little Port Walter	
	Little Port Walter	93–99	proximate		

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: ADF&G					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
		LOCATION: CRYSTAL LAKE			
Coho	Green River, WA	72–73	Washington (state)	Ward Lake	Washington state hatchery stock
	Blind Slough	73–78	SE/same district	Crystal Creek, Mendenhall, Salmon Creek, Sheep Creeks	
	Bear Lake	74–76	SC/Seward	Crystal Creek	
	Ship Creek	74–77	SC/Anchorage	Mendenhall River	
	Duncan Salt Chuck	78–81	SE /same district	Crystal Creek	
	Crystal Creek	79–98	proximate	Crystal Creek, Ohmer Creek, Irish Creek, Sumner Creek, Slippery Creek, St Johns Creek	
	Slippery Creek	86–87	SE/nearby district	Slippery Creek	
	St Johns Creek	86–87	SE /same district	St Johns Creek	
	Mitchell Creek	92–96	SE /same district	Mitchell Creek	
	Portage Creek	92–93	SE/nearby district	Portage Creek	
Chinook	Chignik River	71–73	AP/Chignik	Crystal Creek	
	Ship Creek	71–75	SC/Anchorage	Crystal Creek	
	Chickamin River	75–76	SE/nearby district	Crystal Creek	
	Nakina River	75–76		Crystal Creek	
	Andrew Creek	75–79	SE/nearby district	Crystal Creek	
	King Salmon River	76–77	SE/nearby district	Crystal Creek	
	Farragut River	83–93		Farragut Lake	
	Tahini River	84–86		Tahini River	
	Harding River	86–92		Harding River	
	Crystal Creek	81–99	proximate		

OPERATOR: KHC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
		LOCATION: DEER MOUNTAIN			
Coho	Ketchikan Creek	74–98	proximate	Ketchikan Creek, Ward Lake	
	Reflection Lake	86–94	SE/same district	Ketchikan Creek, Ward Lake Reflection Lake, Margaret Lake	
	Ward Lake	90–95	SE/same district	Bold Island Lake, Ketchikan Creek, Ward Lake	
Chinook	Unuk River	77–82	SE/same district	Ketchikan Creek	
	Ketchikan Creek	81–99	proximate		

Table A2. Broodstock history (hatcheries operating in 1999): Cook Inlet Region.

OPERATOR: PGHC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: PORT GRAHAM					
Pink	Port Graham River English Bay River	90–00	proximate	Port Graham	
Sockeye	English Bay River	89–00	proximate	English Bay	
Coho	Port Graham River	96-98	proximate	Port Graham	

OPERATOR: CIAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: TRAIL LAKES					
Coho	Bear Lake	89–99		Bear Lake	
Sockeye	Tustemena Lake	90–99		Tustemena Lake, Kirschner Lake, Leisure Lake, Hazel Lake	
	Packers Lake	90–97		Packers Lake, Grouse Lake	All Trail Lakes hatchery fish for remote release
	Hidden Lake	89–99		Hidden Lake	
	Chelatna Lake	89–95		Chelatna Lake	
	Big Lake	98–99		Big Lake	
	Upper Russian Lake	89–91		Bear Lake	
	South Fork Big River	89–92		Bear Lake	
	Bear Lake	92–99		Bear Lake	
LOCATION: TUTKA BAY					
Pink	Tutka Creek		proximate		

OPERATOR: ADF&G					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: FT. RICHARDSON					
Coho	Ship Creek		proximate	Ship Creek, Bird Creek, Campbell Creek	
	Little Susitna River			Ship Creek, Bird Creek, Campbell Creek	
	Jim Creek Bear Lake			Eklutna Homer, Seward	
Chinook	Deception Creek			Willow Creek	
	Ninilchik			Ninilchik	
LOCATION: TUTKA BAY					
Chinook	Ship Creek		proximate	Ship Creek	
	Moose Creek			Eklutna	
	Crooked Creek			Crooked Creek	
	Ninilchik			Halibut Cove, Seldovia, Homer, Seward	
	Deception Creek			Whittier, Valdez, Cordova	

Table A3. Broodstock history (hatcheries operating in 1999): Prince William Sound.

OPERATOR: PWSAC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: KOERNIG					
Pink	Duck River	76	PWS/same district		Even year source
	Larson Creek	75–76	PWS/same district		Both odd and even year source
	Ewan Bay	75	PWS/same district		Odd year source
	Koering	78–99	proximate		Wild fish mixed with hatchery broodstock
LOCATION: NOERENBERG					
Pink	Koering	85–89			Hatchery source
	Noerenberg	89–99	proximate		
Chum	Wells River		Same region		
Coho	Mile 18 Creek		Same region		
	Power Creek		Same region		
	Corbin Creek		Same region		VFDA hatchery stock
LOCATION: CANNERY CREEK					
Pink	Cannery Creek	78–99	proximate		
LOCATION: MAIN BAY					
Sockeye	Eyak Lake		Same region		Early Run
	Coghill Lake		Same region		
	Eshamy Lake		Same region		
LOCATION: GULKANA					
Sockeye	Gulkana River	73–99	proximate		Onsite incubation boxes

OPERATOR: VFDA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: SOLOMON GULCH					
Pink	Valdez Arm	81–82	PWS/same district		
	Solomon	83–99	proximate		
Coho	Corbin Creek		proximate		

Table A4. Broodstock history (hatcheries operating in 1999): Kodiak Island.

OPERATOR: KRAA					
Species	Source	Years	Distance	Remote Release	Comments
LOCATION: KITOL BAY					
Pink	Big Kitoi Creek	72–99	proximate		
Chum	Sturgeon River	81–85			
	Big Kitoi Creek	86–99	proximate		
Coho	Buskin River	82–85			
	Little Kitoi Lake	83–92	proximate		
	Big Kitoi Creek	93–99	proximate		
LOCATION: PILLAR CREEK					
Coho	Buskin River	93–00			Stocked in Kodiak road system lakes
Sockeye	Afognak Lake	91–00		Hidden Lake, Big Waterfall Lake, Little Waterfall Lake, Crescent Lake	All for remote release sites
	Laura Lake	93–00		Laura Lake	
	Malina Lake	91–00		Malina Lake	
	Saltry Lake	94–00		Spiridon Lake Ruth Lake	

APPENDIX B

SOUND SCIENCE REVIEW AND PLANNING TEAM RESEARCH OBJECTIVES

CONSERVATION

1. Estimate the extent and causes of migration (straying) between Prince William Sound salmon local populations.

2. Describe microclimate environmental differences and connection to genetic differences.

3. Evaluate hatchery management and fish cultural effects on straying.

4. Determine extent of outbreeding depression by appropriate controlled experimentation.

ECOLOGY

1. Determine distribution and abundance of prey, species composition, and ocean temperature along the migratory pathway.

2. Estimate growth rate of the early life stages of pink salmon.

3. Monitor bioenergetic model of growth and describe changes in optimal growth conditions over time.

4-7. Four proposals having to do with various aspects of monitoring primary production in Prince William Sound.

8. Monitor predation models focused on how predator distribution responds to localized, short-term aggregations of vulnerable prey (hatchery releases).

9. Monitor the effect of pink salmon production on regional predator population size.

MANAGEMENT

1. Identify and characterize the effects of harvest management on hatchery and wild populations.

2. Identify locations outside of hatchery terminal areas that will exploit hatchery populations with low exploitations of wild stocks.

3. Determine geographic areas that are affected by straying.

4. Determine the relationship of run entry timing and straying potential of hatchery stocks.

5. Improve precision and accuracy of forecast methods to identify run strengths of individual hatcheries.

Senate Resources 02.21.24 note: Hillstrand Attachment #5

Cracking the Code: Scientists Use DNA to Examine Differences between Hatchery and Wild Chinook Salmon in Southeast Alaska

February 14, 2024 Hatchery-reared salmon show genetic differences from wild populations in only a few generations, but those differences vary among hatcheries.|

A new genetic study shows hatchery salmon's adaptation to their environment can lead to potentially adaptive genetic differences between hatchery and wild salmon populations in only a few generations. The collaborative research was conducted by scientists from the Alaska Fisheries Science Center, Alaska Department of Fish and Game, and Texas Christian University. It's some of the strongest and most fine-scale evidence to date of these differences.

Pacific salmon hatcheries are used to increase harvest opportunities and supplement declining wild populations.

However, evidence suggests that hatchery rearing can inadvertently select for traits that may be disadvantageous in the wild. This could have downstream implications for native stocks, if these fish breed with wild fish when they are released. One of the goals of this study was to identify the genetic signatures of hatchery-induced adaptation, known as domestication selection. The information could aid in the development of management approaches that reduce unwanted change in hatchery-reared fish.

Several published studies have investigated domestication selection in Pacific salmon on a genomic level. However, this is only one of two studies that paired samples of hatchery-raised fish and their stock of origin from several locations.

Domestication selection is the primary mechanism that leads to reduced fitness (the ability to survive and reproduce) for hatchery fish. Yet, scientists do not know which traits may be driving the observed fitness reductions. They also don't know how it may affect the ability of hatchery salmon to adapt to future environmental change.

"We don't know if domestication selection acts consistently across hatcheries, or if responses of salmon are unique to each facility. The purpose of our study was to determine if levels of domestication selection varied among hatcheries and if there were any commonalities across the populations," said lead author and Texas Christian University student Natasha Howe.

"For example, if we observed the same pattern across all hatchery populations at certain locations in the genome, then that would be pretty striking evidence that those regions are likely influenced by hatchery rearing. Then, we could target those regions in future studies to understand what's driving domestication. We predicted that hatchery practices could have a large influence on the amount of domestication selection occurring. Hatchery practices that prioritize genetic diversity can potentially reduce the genetic impacts of domestication," added Howe.

Domestication Selection in Salmon Hatcheries

Unlike most methods of captive breeding, hatchery-reared salmon are released into the wild once they complete their freshwater juvenile life stage. Juvenile fish in hatcheries are reared in a stable environment with abundant food and no predators. As a result, compared to wild fish, hatchery fish show:

- Increased competitive behavior and aggressiveness
- Faster growth
- Reduced predator avoidance

The stable environment also increases their survival rates at this early stage of development. For example, egg to smolt survival in hatcheries is commonly greater than 85 percent, compared to 1–10 percent in the wild.

However, when hatchery fish are released into the wild, they generally have reduced reproductive success and decreased survival rates compared to their wild counterparts. This poses a risk to wild populations if hatchery-reared individuals interbreed with wild individuals.

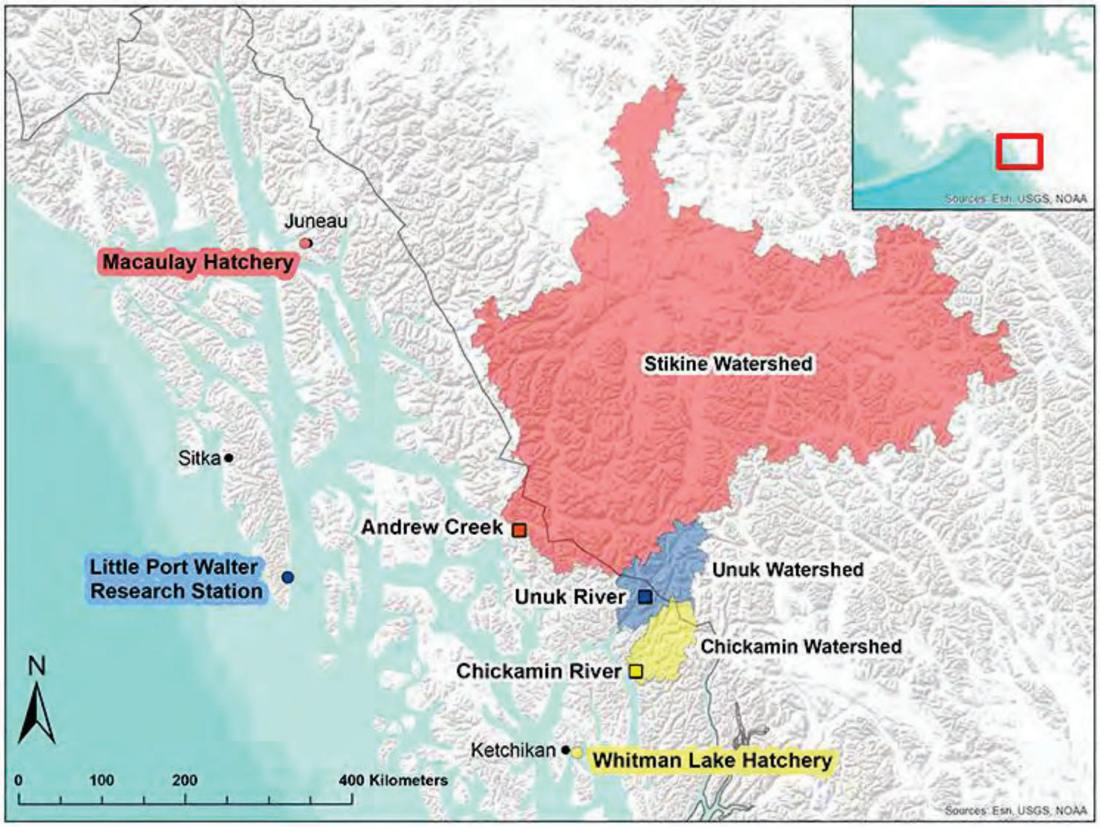
Whole Genome Sequencing

All organisms (bacteria, plants, animals) have a unique genetic code, or genome, that is composed of organic molecules (Adenine (A), Cytosine (C), Guanine (G) and Thymine (T)). If you know the sequence of the molecules in an organism, you have identified its unique DNA fingerprint, or pattern. Determining the composition and order of these molecules is called sequencing. Whole genome sequencing is a laboratory procedure that determines the composition and order of molecules in the genome of an organism and how the order may vary between organisms. This is helpful for scientists studying domestication selection because it allows them to view genomic differences across a population, rather than only an individual.

Scientists used whole genome sequencing to look for signals of domestication selection in three separate hatchery populations of Chinook salmon in Southeast Alaska. Credit: NOAA Fisheries

Scientists used whole genome sequencing to look for signals of domestication selection in three separate hatchery populations of Chinook salmon in Southeast Alaska. In Alaska, salmon hatcheries are primarily intended to enhance fisheries rather than to directly supplement wild populations.

Differences Among Hatchery Populations



Site map of Southeast Alaska and the corresponding locations for each hatchery population (circle) and corresponding wild population (square). Matching colors are indicative of hatchery-wild population pairs. Credit: Natasha Howe.

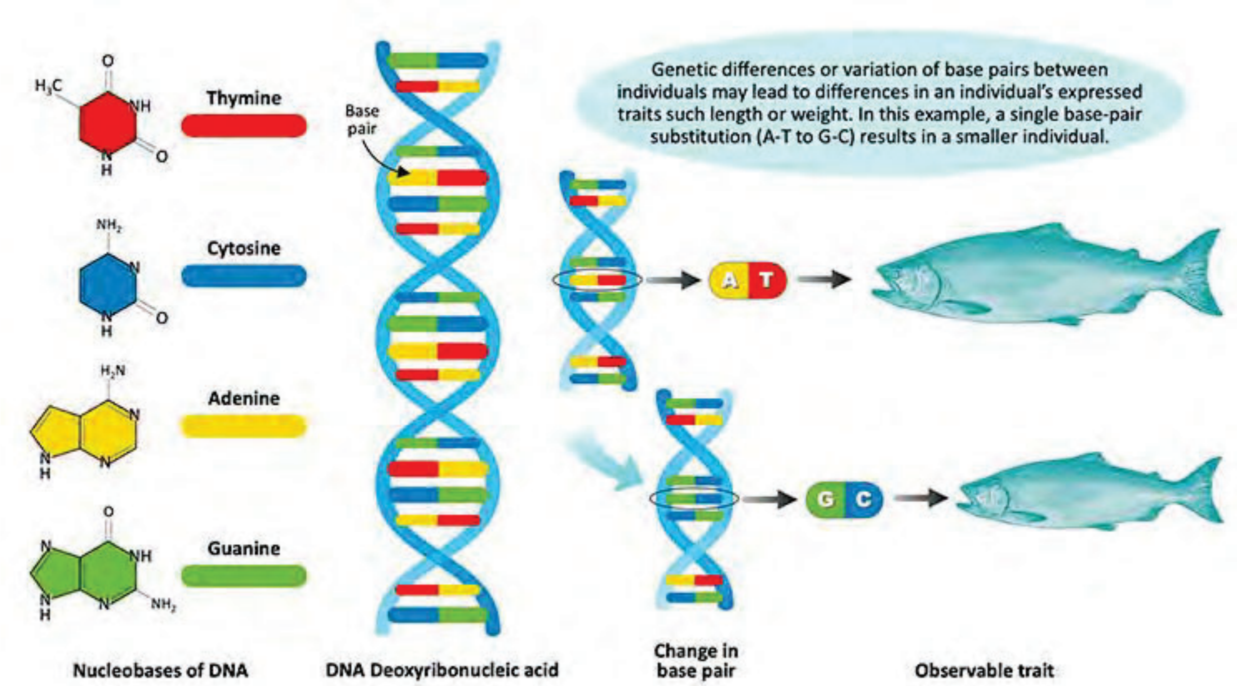
The three hatchery populations selected for this study differed substantially in their fish culture methods and goals. Whitman Lake Hatchery and Macaulay Hatchery are production-focused hatcheries. They produce larger numbers of fish (returns larger than 10,000; broodstock sizes greater than 400) to supplement commercial and recreational fisheries. The fish in Whitman Lake are descendants of fish collected from the Chickamin River. The Macaulay Hatchery brood is derived from Andrew Creek, a tributary of the lower Stikine River.

Scientists found that hatchery lines from all three hatcheries were subtly to moderately diverged from their wild stocks of origin. This is not surprising since these hatchery populations have been separated for approximately 30–40 years.

Notably, the Andrew Creek and Chickamin stocks at Macaulay and Whitman lake hatcheries were more similar to their wild populations than the Unuk stock at Little Port Walter. This finding is largely due to the fact that the production-focused facilities spawn more fish each year than the smaller, research-focused facility. This is good news, as larger populations can help preserve overall genetic diversity.

“Interestingly, changes in the genetic sequences between hatchery and wild salmon were not the same across the different hatcheries, suggesting that domestication of hatchery fish can occur through different genetic pathways. Unfortunately, we lacked phenotypic data such as length, weight, and fecundity of individual fish for two of the hatchery populations, so we still do not know which traits are most affected by hatchery rearing," said Charlie Waters, research fish biologist at Alaska Fisheries Science Center and manager of Little Port Walter Research Station.

Looking Ahead



Genetic differences or variation of base-pairs between individuals may lead to differences in an individual's expressed traits such length or weight. In this example, a single base-pair substitution (A-T to C-G) results in a smaller individual. Credit: NOAA Fisheries

The results from this study highlight the need for hatchery monitoring programs to collect paired genotype-phenotype data. The genotype of an organism is defined as the genetic sequence at one or more genes of interest. The phenotype of an organism is the observable physical or biochemical characteristics of an organism (such as length or weight), determined by both genetic make-up and environmental influences.

Identifying the links between the genetic code (genotype) and expressed traits (phenotype) in salmon will be key to future research efforts. It will help scientists and managers understand how the fitness of hatchery fish may be affected and how salmon may respond to changing environmental conditions.

Scientific and technological advances have enabled the rapid generation and screening of genome-wide data to identify associations with selection and the emergence of harmful traits. Research examining the link between genetic code variations and fitness-related traits holds promise. It can offer insights valuable for hatchery management, aiming to reduce domestication selection and safeguard wild stocks. Alaska Fisheries Science Center on February 14, 2024