

ALASKA LEGISLATURE SPECIAL COMMITTEE / SUBJECT FILE 8672
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***Proposal to Conduct a Benefit-Cost Analysis of the Fishery
Enhancement Program:
Emphasis on the Price Responsiveness of Alaska
Salmon to Enhancement Production***

Introduction

In May 1991, the Senate Special Committee on International and Domestic Fisheries initiated an extensive review of the Alaska salmon hatchery and enhancement program. As a result of considerable interest in the project, participation in the Hatchery Research Project includes representatives from both the Senate and the House of Representatives. The purpose of the study is to 1) review the history and legislative intent of the enhancement program, 2) analyze the current status of the program, and 3) consider future options for the program--ranging from fine tuning to possible redirection.

As part of the Hatchery Research Project, an Economics and Marketing study group was developed to provide information to the legislature on the economic impacts of salmon hatchery production. The group is to help determine

- if the current levels of Alaska salmon harvests are over-or under-supplied from a world-market perspective and

- if increased hatchery production of salmon will lower prices, fishing and processing revenues, and the total net value of Alaska's salmon fisheries.

To address these public policy questions requires a benefit-cost analysis. This type of analysis measures the level and cost of enhanced salmon production, the cost of managing, harvesting, and processing enhanced salmon stocks, and the impact or "price responsiveness" of world salmon markets to various levels of Alaska enhanced salmon production. The costs are then subtracted from the benefits to estimate the net benefits of the salmon enhancement program and the incremental net benefits of different levels of enhanced salmon production to commercial fisheries. To analyze only the impact of different levels of salmon production on world salmon markets and prices paid to fishermen is insufficient for thorough policy analysis because it does not measure the net benefits (benefits minus costs) of the commercial salmon fisheries to fishermen or all Alaskans.

An example of some of the policy questions a benefit-cost analysis would help to address are as follows:

- Is increased Alaska salmon hatchery production the cause of this year's lower salmon prices? What is the significance of other factors, such as increased farmed-salmon production, exchange rates, economic recessions, and prices of food substitutes?

- What is the most profitable salmon species mix and level of production for the statewide enhancement program? Should the emphasis shift from pink salmon to king and coho salmon, for example, or even to other non-salmon species?
- If Alaska curtailed hatchery salmon production, would Alaska salmon (both wild and hatchery) prices increase or would the resulting market share be filled by farmed salmon from other countries? Ultimately, what would be the net effect or benefits to Alaskans from these changes?
- How are the estimated benefits and/or costs of the existing hatchery production distributed to fishermen and processors in each region of the state? If changes in production occurred, how would these benefits and/or costs be distributed?
- What would be the economic benefits of changes in policy or additional legislative oversight regarding the production capacity and releases of hatchery salmon?

Rather than initiating a new benefit-cost analysis, the Senate Special Fisheries Committee requested the Hatchery Research Group to first identify the specific issues that need additional economic research. In response, the economics group developed a study plan with the initial tasks of reviewing economic and marketing studies completed to date and assessing the need for additional research.

After reviewing current research, the group determined that insufficient economic information currently exists to accurately address salmon enhancement public policy questions. The research that has been completed is either out-of-date, or additional research needs to be done to improve the reliability of existing economic models. As a result of the significant investment by private parties and the state of Alaska in both enhancement projects and commercial fishing, a rigorous analysis using accepted bioeconomic techniques is warranted to fill these information gaps.

Based on our review, the economics group is proposing a set of contracts for additional research. The group worked closely with staff from the Alaska Department of Fish and Game (ADF&G), FRED Division to develop this proposal because FRED Division staff have considerable experience in these areas of research and have contracted for previous studies. In addition, we have solicited comments from the Divisions of Commercial Fisheries and Sport Fish to ensure that their concerns are addressed. As the committee requested, this proposal builds on previous research to close information gaps. It should be noted that the cost estimates are preliminary and more specific contract language will be developed if the legislature pursues the research.

Proposed Research

The five principal research components are:

- 1) a hatchery production and cost model,
- 2) a fish population model linked to fishing effort and harvests,
- 3) a demand model for Alaska salmon in world markets,
- 4) a fishing cost model, and
- 5) a computer software system to combine the four models.

The five components are described below including researchers and estimated costs. Based on prior research conducted for the FRED Division and expertise, the economics group contacted potential University of Alaska researchers to determine interest in the projects. The researchers identified have submitted proposals for research at the specified funding levels.

As a result of the short time period available to complete the research, it will be funded through RSAs. Therefore, interested parties will not formally bid on the projects, but instead will provide information on proposed research methodology, pertinent research experience and qualifications, and the ability to complete the contract in the time available.

Hatchery Cost and Production Model

Principal Investigators: Economics Group, Legislative Research Agency, and the ADF&G, FRED Division staff

Anticipated Cost: \$0

This research component would consist of a survey of hatchery and enhancement project operators to determine the cost of producing salmon. In economics jargon, survey information will be used to develop an enhancement project "production function" to estimate the incremental cost of changes in the number of salmon produced by these projects. The survey will be developed by the economics group and FRED division staff and administered by the Legislative Research Agency and FRED division. This portion of the research will also solicit information from the ADF&G, Division of Commercial Fisheries regarding the costs of fisheries management of enhancement project stocks.

Biological Population Model

Principal Investigators: Dr. Jeremy Collie, Juneau Center for Fisheries and Ocean Sciences, University of Alaska Fairbanks

Anticipated Cost: \$10,000

The purpose of the biological population model is to estimate the number of adult fish produced by enhancement projects and available for harvesting. Salmon produced by hatcheries and other projects are exposed to similar biological and environmental conditions and fisheries as wild stocks--as compared to farmed salmon. As a result, this research would estimate the interdependence of wild and enhanced stocks. These estimates will be taken into consideration varying management assumptions regarding stock separation and cost recovery.

Salmon Demand Model

Principal Investigator: Dr. Mark Herrmann, Department of Economics, and Dr. Joshua Greenberg, School of Land Resources Management, University of Alaska Fairbanks

Anticipated Cost: \$18,000

This contract will extend and improve research on the salmon enhancement program completed to date by Dr. Boyce for the FRED division. To more fully understand world salmon markets, improvements to existing demand models are needed. Relatively little research has been conducted to date on the demand for Alaska salmon, and models that do exist are insufficient to reliably answer the Legislature's policy questions. The additional work has not been contracted by the FRED because of insufficient funding. There are two major improvements needed. The first is in the ability to forecast salmon prices and the amount of price responsiveness to changes in enhanced salmon production and harvest levels. The second improvement is incorporating the impact of changes in world salmon-farming production levels on Alaska salmon markets and prices.

Fishing Cost Model

Principal Investigator: Dr. John Boyce, Department of Economics, University of Alaska Fairbanks

Anticipated Cost: \$20,000

This portion of this study will estimate the cost to fishermen of harvesting salmon to determine the incremental cost of harvesting different levels of enhancement project produced fish. This information can address questions such as--if hatchery production results in a 10 percent increase in harvest levels and a 2 percent decrease in the price of pink salmon, are the additional revenues minus the additional cost of harvesting the fish sufficient to increase fishermen's net revenues. Little extensive or reliable research has been completed on this topic which accounts for the relatively higher cost of this study component.

Combining of Models

Principal Investigator: Drs. John Boyce and Mark Herrmann, Department of Economics, and Dr. Diane Bischak, School of Management, University of Alaska Fairbanks

Anticipated Cost: \$10,000

When completed, the four models will be combined into a single, complete software system for the analysis of specific policy questions. This contract will test specific future enhancement program options--such as maintaining, decreasing, or increasing current enhanced salmon production levels, changing the current species mix, and maintaining or changing the location of enhancement projects--on the net economic benefits to fishermen and Alaskans. To the extent possible the analysis will differentiate the distribution of enhancement program net benefits among regions of the state. The results of this analysis will be a written report for the committee that will facilitate the development of public policy decisions.

Conclusion

In addition to providing information on Alaska's salmon enhancement programs, the models developed by the study could be used for evaluating other salmon management policy questions.

The total estimated cost of the research is \$58,000 which is approximately \$17,000 less than the UAA, Institute of Economic and Social Research proposal provided in May 1991. The reasons for the estimated lower costs are that the hatchery cost model work would be done with current legislative and ADF&G staff.

The research proposed does not include studies to develop new markets or products for Alaska salmon for a number of reasons. The time available is insufficient, the cost of reliable marketing studies is usually quite high, and the Alaska Department of Commerce and Economic Development (DCED), Division of Economic Development and the Alaska Seafood Marketing Institute (ASMI) are both initiating salmon marketing studies in response to this summer's lower salmon prices. Therefore, the legislative economics and marketing group plans to provide information to the legislature on the success of past state efforts to market Alaska salmon and coordinate with the DCED efforts to avoid research duplication and encourage the best possible information. A copy of the DCED proposal is attached.

The proposed research also does not include studies to estimate the net benefits of the salmon enhancement program to sport or subsistence users. Including these additional uses would significantly expand the scope and cost of the studies.

October 28, 1991

Fishing Cost Model Progress Report

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May 4, 1992

Introduction

The fishing cost model estimates the economic profits accrued to the harvesting sector as a function of the harvest size and value. To analyze the costs and benefits of the Alaska salmon enhancement program, it is necessary to predict how changes in the size and value of the harvest affect participation choices by fishermen. This document summarizes the modeling approach as well as progress to date.

Observations and hypotheses

Even though the salmon fisheries are limited entry fisheries, the number of fishermen actually participating at any point in time is generally less than the number who could be participating. Why are we not observing all of the fishermen participating when the fishery is open? The answer appears to be that the fishermen vary with respect to fishing costs.

The central hypothesis underlying the fishing cost model is that higher profits invite greater participation in the fisheries. Information on profits (profits = revenues - costs) is not collected by the state. The state does, however, collect data on revenues as well as participation by fishermen. In its simplest form, the fishing cost model uses expected gross revenues to explain participation rates. If fishermen were the same, this procedure would determine a threshold gross revenues above which participation would occur, and below which participation would not occur. Then we should observe fluctuations between "no one fishing" and "everyone fishing" as average gross revenues fluctuate below and above the cost threshold. This, however, is not what is observed. What we observe is a pattern showing as gross revenues increase, the participation rates increase. This suggests that fishermen do not have identical costs. Some fishermen have higher costs than others.

To estimate the profits to the industry, we must have some measurable variable that differentiates between the fishermen with higher and lower costs. Several hypotheses have emerged. The first is that the costs fishermen have are related to characteristics

about the configuration of the equipment the fisherman uses. For example, larger vessels might be more costly to operate, therefore requiring a better return before they are willing to participate. A second hypothesis is that some fishermen may be more efficient than others. Even though there may be no observable differences in their gear configuration, the more efficient fisherman may be able to fish profitably during days when other less skilled captains cannot. A third hypothesis relates to the effect of congestion in a fishery. It is hypothesized that as the number of fishermen in an area increases, the return to each fisherman per day of effort declines because of fishermen are getting in each other's way.

The fishing cost model may be summarized as being comprised of the following hypotheses:

H_0 : Higher gross revenues attract greater participation.

H_1 : Fishing costs are related to gear configuration.

H_2 : Fishing costs are related to inherent differences in the fishermen.

H_3 : Fishing costs increase with the number of fishermen participating.

The methodology

Data were purchased from the Commercial Fisheries Entry Commission (CFEC) for a number of the major salmon fisheries served by the enhancement program in Alaska. In particular, we have obtained data for the following fisheries for the years 1990 and 1986:¹

Table One: FISHERIES ANALYZED

Cook Inlet	drift net, set net, and purse seine
Kodiak	set net and purse seine
Prince William Sound	drift net and purse seine
Southeast	hand troll and power troll

¹We chose the year 1990 because it was the most recent year for which data has been completely compiled. We requested each of the years from 1984 through 1990, but this would have accounted for over 50% of the funding for this portion of the project. 1986 was chosen in consultation with CFEC staff because it is a fairly representative year.

The data CFEC collects for these fisheries includes *fish ticket file* data, which describes the harvesting patterns of each member of the fleet, the *permit file* data, which describes the range of permits held by each member of the fleet, and the *vessel file* data, which describes the configuration of the vessel(s) used by each member of the fleet.

The fishing cost model requires the data to be organized by fisherman and by opening. The idea is to predict whether or not the fisherman will participate in the opening. For each fisherman, we observe the days they did and did not participate, and the revenues they and others earned in each fishery that was active. We also know what vessel or equipment the fisherman was using and we know how each fisherman compares with others in the fleet in matters such as average catch, number of days active, number of areas visited, and number of processors sold to.

For each day there is fishing, we observe whether or not the fisherman participated. The model predicts whether or not the fisherman will participate on the basis of (1) expected gross revenues, (2) the configuration of the vessel, (3) systematic differences in the skills and behavior of the fishermen, and (4) the number of other fishermen in the fishery. These four sets of factors correspond to the four hypotheses stated above.

What we have found

Most of the research time to date has been spent organizing the CFEC data files to test the four hypotheses listed above. These hypotheses test the relative importance of each factor on participation in a particular fishery and opening. As a result of the very large data sets used for this modeling effort and extensive computer programming requirements, this work is still in progress but will not delay the final combined report. This report primarily presents findings from the Cook Inlet purse seine fishery.

The Cook Inlet purse seine fishery operated in 1990 over a season of 85 days. There were 73 fishermen who participated. The Cook Inlet purse seine fishery regularly had openings of 5-6 days in length. The Cook Inlet purse seine fishermen on average participated slightly over 16 days, and earned approximately \$1200/day, for total gross revenues of about \$19,500 per fisherman. None of the fishermen were active the entire season.

The fishermen participating in the Cook Inlet purse seine fishery vary considerably from one another in terms of their gross revenues. Table Two shows the mean, standard deviation, maximum and minimum value for a set of selected summary statistics for the Cook Inlet purse seine fleet. A good rule of thumb for reading standard deviations is that approximately 35 percent of the sample will have values outside of the range of the mean plus and minus the standard deviation. Thus 35 percent of the fishermen earned revenues less than \$100/day or greater than \$2200/day. Therefore, it appears that the fishermen do not behave in the same way or possess the same skills. This suggests that fishermen do have different levels of profits. This lends support to the assumption of hypothesis H₂, that fishermen have different inherent skills and behavior.

The fishermen in the Cook Inlet purse seine fishery are also quite different in the configuration of the vessel that they use. Table Three shows summary statistics for the vessel characteristics. The vessels differ in hold capacity, length, gross tonnage, and engine type and horsepower. This evidence suggests that fishermen probably have different operating costs. This data was used to these costs depend systematically upon the configuration of their vessel that depend, among other things, upon the configuration of their vessel. This lends support to the assumption of hypothesis H_1 that fishermen have different costs associated with the configuration of their vessel.

Table Two

VESSEL DESCRIPTIVE STATISTICS (COOK INLET PURSE SEINE FISHERY, 1990)

Variable	Mean	Std Dev
VALUE OF VESSEL	\$54,992.65	\$60,728.57
YEAR VESSEL BUILT	1975.88	12.51
VESSEL LENGTH	32.53	8.04
GROSS TONS	12.17	12.99
HORSE POWER	254.19	123.74
HOLD CAPACITY	1660.75	6308.93
FUEL CAPACITY	359.41	300.33

Table Three

FISHERMEN DESCRIPTIVE STATISTICS (COOK INLET PURSE SEINE FISHERY, 1990)

Variable	Mean	Std Dev	Minimum	Maximum
NUMBER OF DAYS ACTIVE	16.46	8.10	1.00	33.00
CATCH (LBS) PER DAY FISHED	1359.08	1008.89	242.16	6202.75
GROSS REVENUES PER DAY FISHED	1191.92	1023.06	187.09	7598.02
LENGTH OF ACTIVE SEASON	37.32	16.24	1.00	76.00
NUMBER OF AREAS VISITED	3.72	1.85	1.00	9.00

The hypothesis H_0 postulates a relationship between participation and gross revenues that exists *holding all else constant*. Thus we control for each of the other hypothesized effects on participation when testing for this effect. We have found strong support for this hypothesis. The probability that a fisherman will participate in a fishery increases as the gross revenues they may expect to earn increases. This means that fishermen do have different thresholds above which they earn profits and below which they do not.

The hypotheses H_1 and H_2 attempt to discern *which* fishermen have higher costs. These hypotheses are tested by using variables from Tables Two and Three, respectively, to predict participation rates. With the Cook Inlet purse seine fishery we have found weak support for these hypotheses. That is, some but not all of the variables on these lists help predict whether or not a fisherman will participate in a particular opening.

The evidence is mixed in regards to the hypothesis that observable differences in the behavior and skill of the captain contribute to differences in profitability. For the Cook Inlet purse seine fleet, we found some evidence that fishermen who make more trips are less likely to continue participating in a particular opening if the fishing is bad, but fishermen who participate more days of the year are more inclined to stick around. We measured the summary statistics for each fisherman for the year 1986 to predict their behavior in 1990. This was done to disassociate the influence their decision in a particular day with the statistic describing their behavior over the whole season.

The congestion hypothesis H_3 is only weakly supported also. We found that the number of fishermen who were in the fishery the previous day had a positive effect upon whether or not a fisherman would remain in the fishery today. This suggests that when the fishing is good, fishermen participate regardless of how many other fishermen there are.

Table Four

PRELIMINARY RESULTS FROM COOK INLET PURSE SEINE FISHERY

H_0 : Higher gross revenues attract greater participation.	STRONG SUPPORT
H_1 : Fishing costs are related to gear configuration.	SUPPORT
H_2 : Fishing costs are related to inherent differences in the captains.	SUPPORT
H_3 : Fishing cost increase with the number of fishermen participating.	WEAK SUPPORT

We have relatively good prediction statistics. For entry into the fishery, we are able to predict correctly whether or not the fisherman will enter over 90 percent of the time. Once a fisherman is in the fishery, our ability to predict whether or not they will stay is over 60 percent accurate. However, while we are very accurate at predicting whether or not someone will not enter the fishery, most of our success in predicting that people will stay out of the fishery. For those who do actually enter, our prediction rate is less than 50 percent. Similarly, while we are very accurate on predicting whether or not a fisherman will stay in the fishery, we are less accurate in predicting accurately for those who leave the fishery.

We suspect that some of our inaccuracy is due to not yet having adequately constructed a variable that controls for whether or not the fisherman is already active in another statistical area. Likewise, we suspect that many of the people who exit one area are doing so to participate elsewhere. We are in the process of constructing variables to measure these effects.

What remains to be done

We have yet to examine a number of the fisheries, including both the troll fisheries in Southeast, the drift net and purse seine fishery in Prince William Sound, the set and drift net fisheries in Cook Inlet, and the Kodiak purse seine and set net fisheries.

We have not yet made a calculation of the net profits that accrue to a particular area given the size of the harvest and the average price received by fishermen.

**An International Marketing Model for Alaska Salmon
Progress Report: Executive Summary**

May 1, 1992

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The purpose of this report is to give a progress report on the economic demand component of the Legislative Review of Alaska's Fisheries Enhancement Program and may not be quoted elsewhere without the permission of the authors. This report was made possible by a grant received from the Alaska State Legislature and is the result of research sponsored by Alaska Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, under grant no. NA90AA-D-SG066, project #R/14-13, and from the University of Alaska with funds appropriated by the state.

Abstract

This report is an executive summary of work performed to date on the salmon demand model portion of the Legislative Review of Alaska's Fisheries Enhancement Program contracted by the Senate Special Committee on Domestic and International Commercial Fisheries. As this reports on work in progress, reported theoretical models and preliminary findings are likely to differ slightly from the final analysis. For example, the final analysis will use a 1991 data set that is not complete at the time of this report.

The theoretical work on this portion of the project develops a 94-equation equilibrium supply and demand model for Pacific and Atlantic salmon. This system of equations includes various market components that affect Alaska salmon exvessel prices. The objective of this modelling effort is to project future Alaska salmon exvessel prices under various market scenarios that can ultimately be used in a cost/benefit analysis.

The modelled systems can be broken into two connected parts. The main body of the model is a 49-equation bloc in which salmon is traded among North America, Japan, the European Economic Community¹ (EEC), Chile, Australia, and New Zealand. Both fresh/frozen and canned salmon firms are modelled. The salmon species were divided into fresh/frozen farmed Atlantic, farmed Pacific, high-valued wild Pacific, low-valued wild Pacific, and canned low-valued wild Pacific salmon. The flows will be modelled recursively into two North American Pacific salmon exvessel prices (for high- and low-valued salmon). Quarterly data from 1982 to 1991 is used for this part of the model.

The second part of the model is a 45-equation bloc in which Alaska exvessel prices by species, region, and gear type are correlated with the North American exvessel prices from the main body of the modelling. Specifically, chinook, sockeye, and coho prices are correlated against North American high-valued Pacific salmon exvessel prices, and chum and pink prices are correlated against North American low-valued Pacific salmon exvessel prices. The purpose of this second set of equations is to analyze the salmon demand modelling results by region, species, and gear type for the fisheries in the state with the largest enhanced production component.

Early results indicate that Alaska exvessel salmon prices may be more responsive to landings than previously believed. This leaves open the possibility that, in higher yielding years, Alaska hatcheries may be producing near the economic optimum number of salmon. But, even if the demand portion of the project were completed, this conclusion could not be stated with certainty until it is integrated and simulated with the cost and biological project components. The bulk of the effort on the demand portion of the project has so far been spent building the theoretical model and collecting data. The model results reported are very preliminary, and given their potential ramifications, this study must continue to be done carefully, with specific attention to paid achieving model accuracy.

¹ The region designated as the European Economic Community (EEC) will, for this study, include all of the EEC member countries (Belgium, Luxembourg, Denmark, West Germany, France, Ireland, Italy, Netherlands, United Kingdom, Greece, Portugal, and Spain) as well as Sweden and Switzerland.

Introduction

The purpose of this project is to describe the relationship between salmon prices and quantities, and the various market conditions that can influence these variables. The relationships between market factors and salmon prices have a hypothesized structure. By using econometric techniques, we can test the validity of this hypothetical structure. Econometrics is a blending of economic theory and regression analysis. Through model estimation, the developed system of equations can provide a framework for predicting, under various market conditions, future salmon quantities and prices.

The current econometric model is being constructed with the specific objective of developing long-term forecasts. Alaska salmon exvessel prices by region, species, and gear type will be forecasted to facilitate the incorporation of these projections into a cost/benefit analysis of Alaska's salmon hatchery system. Additional benefits of this modelling effort include obtaining estimated mean-level and point elasticities (an economic term measuring relationships among variables), as well as obtaining results from the sensitivity analysis.

Project Goals

Following are the specific objectives of the international market modelling section of the salmon enhancement study. These objectives are modified from those found in the original proposal as necessitated by knowledge gained in initial modelling efforts. The following objectives are more specific than those found in the original proposal.

The specific objectives of this project are as follows:

- 1) Update the existing international econometric salmon model of fresh/frozen salmon as published in a work by Mittelhammer, Herrmann, and Lin for the National Marine Fisheries Service entitled *An Economic Analysis of World Salmon Markets: Effects of Salmon Farming*, using 1988 and 1990 data (and possibly 1991). Quarterly data will again be used (Also see Herrmann 1990).
- 2) Examine the possibilities of changing the functional form of the relevant equations in the above models to linear (or log-linear) instead of double-log to allow for changing elasticities along the demand curve.
- 3) Expand the model to include can red pink and chum salmon (canned chum salmon is merely added to keep the definition of low-valued salmon intact. Canned chum salmon is relatively insignificant in terms of overall quantity).
- 4) Model at the exvessel and export levels. Factors affecting the wholesale level will be included in the reduced form exvessel price equations.
- 5) Disaggregate the salmon species at the exvessel level into Alaska chinook, sockeye, coho, chum, and pink salmon by area and gear type. Current targeted fisheries are Prince William Sound drift gill net and purse seine, Cook Inlet drift gill net, purse seine and set net, Kodiak purse seine and set net, and Southeast hand and power troll. (For the

final report these targeted areas may be altered). In an attempt to locate regional price changes, these areas are being modelled by relating the aggregate North American prices of salmon to the regional prices of salmon in Alaska through correlation analysis.

6) Report all relevant own-price, cross-price, and income elasticities. Cross-price elasticities will be between relevant Pacific and farmed salmon species.²

7) Perform sensitivity analyses over the historical time period to validate the models and to answer questions as to the effects of cases 1-11 found in the original RFP (see appendix A) over the historical time period. Sensitivity analysis will also be done on various market factors such as changing exchange rates, tariff rates, income levels, etc. This sensitivity analysis may be performed independently of the entire demand, cost, and biological model, or may be done exclusively as a part of the final integrations of the three models.

8) Prepare the model to be used in the "Combining of Models for Policy Analysis" part of the enhancement project. This will include price predictions and sensitivity analysis on future prices for cases 1-11.

9) To write a final report with a targeted finish date of October 1992.

A progress report of the work completed to date can be found in Appendix B.

The Theoretical Model

Econometric models are constructed with an end goal in mind. The purpose of this model is to project salmon price over a long time horizon. This necessitates a different type of model than would be constructed if the goal was to forecast one year in advance. A model with a goal of forecasting one year in advance might include ADF&G forecasted biomass; current United States, Canadian, and Japanese inventory levels; and other variables. Unfortunately, these variables are not available for inclusion in a model with a 15-year forecasting horizon.

A model that is geared toward multi-year predictions cannot use variables such as ADF&G forecasts of salmon runs and actual inventory figures. Instead, model-generated salmon landings must replace ADF&G forecasts, and predicted inventory levels must replace actual inventory levels. Additionally, future values of other market factors, such as exchange rates, must also be projected into the future in order to predict salmon prices.

This long-run emphasis necessitates an aggregate modelling approach that emphasizes accurately estimating trends in long-term price movements rather than accurately estimating the price in any single year. In other words, the model will have achieved its objective if at any point in time it is able to predict mean price levels for the next ten-

² An elasticity measures the percentage change in a dependent variable for a one-percent change in an independent variable, holding all other variables constant. For example, if the price of farmed salmon increases by 1 percent and the quantity demanded decreases by 1.5 percent, then the own-price elasticity of farmed salmon is -1.5.

year time period better than a naive expectation. This will be true even if the variance of the model estimates are high indicating that any single year's predictions are not entirely accurate.

Because world salmon markets are highly integrated, an international approach to modelling was necessary. The flowchart gives a visual representation of the salmon model that is being constructed. The arrows show the direction of trade flows that are being modelled.

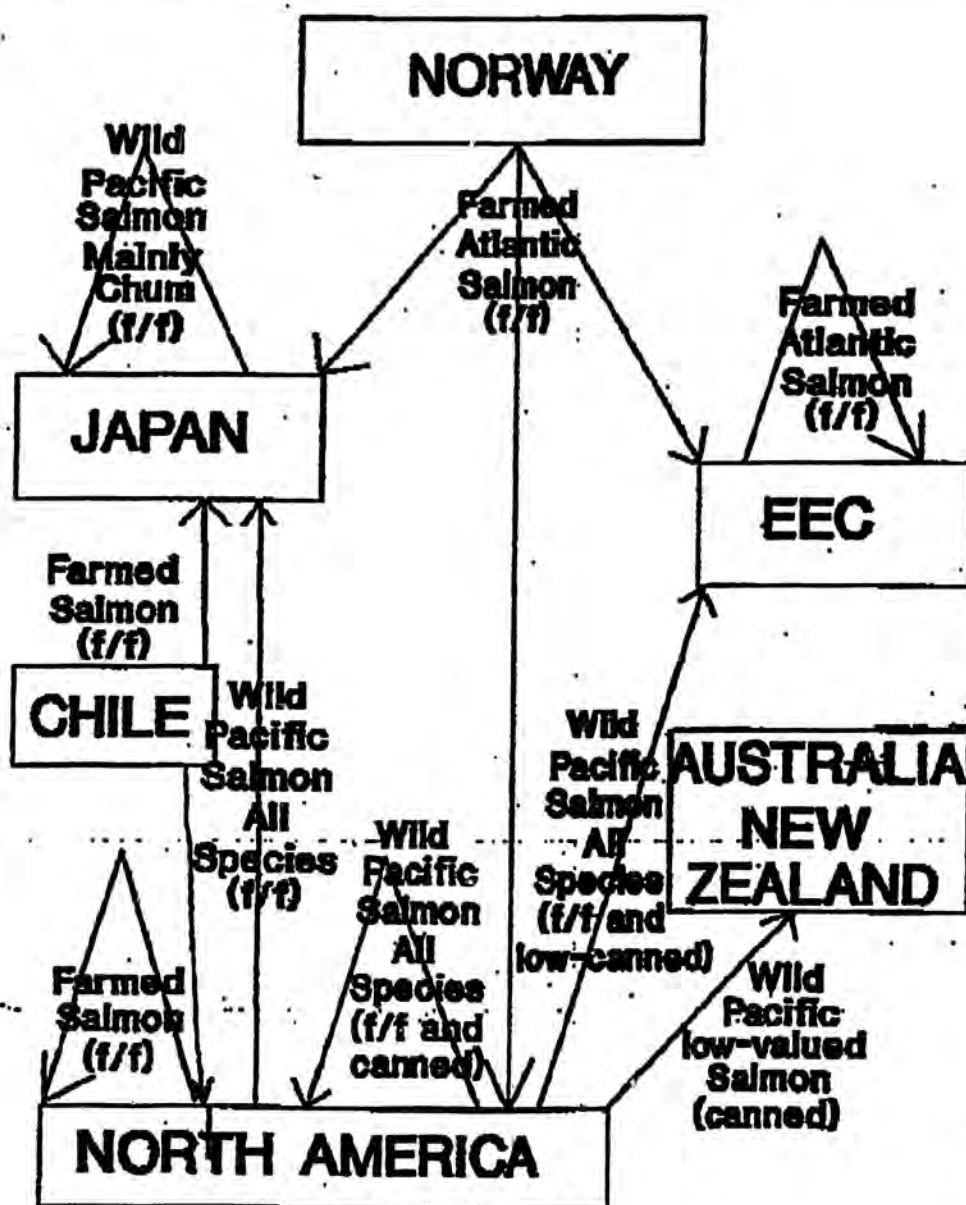


Figure 1. International salmon flowchart. (Note: f/f indicates fresh/frozen).

Listed below are the dependent variables that are being modelled in bloc 1. The final model may be somewhat different. All quantities are fresh/frozen unless otherwise noted as canned.

1. Norwegian allocation of farm-raised Atlantic salmon
 - Quantity allocated to the EEC
 - Quantity allocated to Japan
 - Quantity allocated to the United States
2. EEC demand for salmon
 - Quantity demanded of Scottish, Irish, and Norwegian farmed Atlantic salmon
 - Quantity demanded of North American high-valued wild Pacific salmon
 - Quantity demanded of North American low-valued wild Pacific salmon
 - Quantity demanded of canned North American low-valued wild Pacific salmon
3. Japanese demand for salmon
 - Quantity demanded of Norwegian farmed Atlantic, Chilean farmed Atlantic and coho salmon
 - Quantity demanded of North American high-valued wild Pacific salmon
 - Quantity demanded of North American low-valued wild Pacific salmon
4. North American demand for Atlantic salmon
 - Quantity demanded of Norwegian, Chilean, British Columbian, and U.S. farmed Atlantic salmon
5. Australia and New Zealand Demand
 - Quantity demanded of canned North American low-valued salmon.
6. North American allocation of high-valued wild salmon
 - Quantity allocated to Japan
 - Quantity allocated to the EEC
7. North American allocation of low-valued wild salmon
 - Quantity allocated to Japan
 - Quantity allocated to the EEC
8. North American allocation of canned low-valued wild salmon
 - Quantity allocated to the EEC
 - Quantity allocated to Australia and New Zealand

9. North American inventory holdings

- Quantity of high-valued wild salmon inventory
- Quantity of low-valued wild salmon inventory
- Quantity of canned low-valued wild salmon inventory

10. North American exvessel prices

- Price of high-valued wild salmon
- Price of low-valued wild salmon

11. Exvessel Regional Mappings

- The exvessel prices of species and regions in Alaska as listed under project objective 5.

The model includes flows of farmed salmon from Norway, Scotland, Chile, British Columbia, Ireland, and the United States. The farmed salmon from Norway, Ireland, and Scotland is exclusively Atlantic salmon. Farmed salmon from the United States, British Columbia, and Chile are a mixture of Pacific and Atlantic salmon. North American salmon exports include all species of Pacific salmon. Japanese landings of salmon also include all species of Pacific salmon, although most Japanese landings are chin salmon.

To keep the model manageable and because of data limitations, some countries and salmon species were aggregated, and some markets were omitted. Aggregated markets include the United States and Canada into 'North America' and European countries into the EEC. Omitted countries include the former Soviet Union which historically has kept its salmon in the Eastern Bloc countries. Despite this, it is felt that the resulting model is sufficiently inclusive to generate insights into the operations of world salmon markets.

In bloc 2 the current Alaska salmon exvessel prices that will be predicted include all species for Prince William Sound drift gill net and purse seine, Cook Inlet drift gill net, purse seine and set net, Kodiak purse seine and set net, and Southeast hand and power troll.

(For the complete model and data variable definition, see Appendix C.)

Estimation Results

For bloc 1, the two equations that have been partially estimated are equations 47 and 48, the North American high-valued exvessel price equations. These equations are reduced form equations based on derived demand theory. For the North American high-valued Pacific salmon exvessel equation, 93.7 percent of the variation in the exvessel prices was explained by the explanatory variables (see figures 2 and 3 which show the historical fit between the actual and predicted exvessel prices for high- and low-valued salmon). One of the findings was that farmed Atlantic salmon substituted with sockeye, chinook, and coho salmon with a 95.1 percent probability.

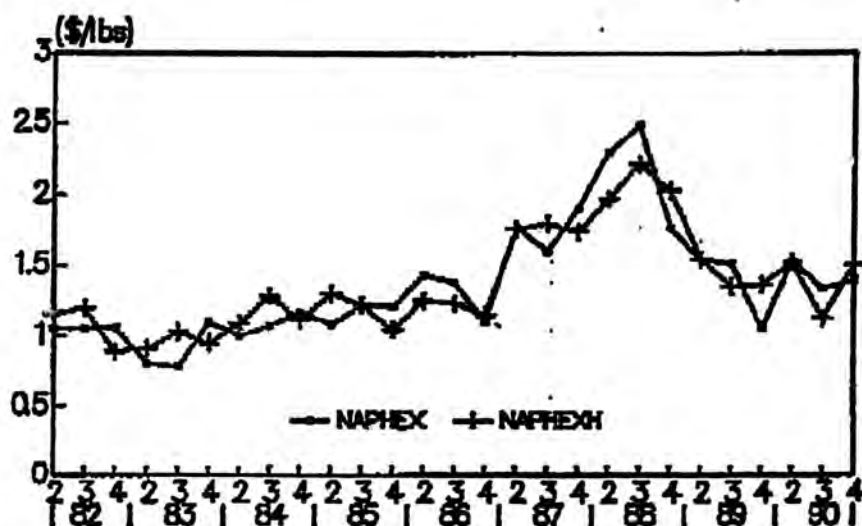


Figure 2. Predicted (NAPHEXH) vs. actual (NAPHEX) North American high-valued salmon exvessel price (1982 to 1990).

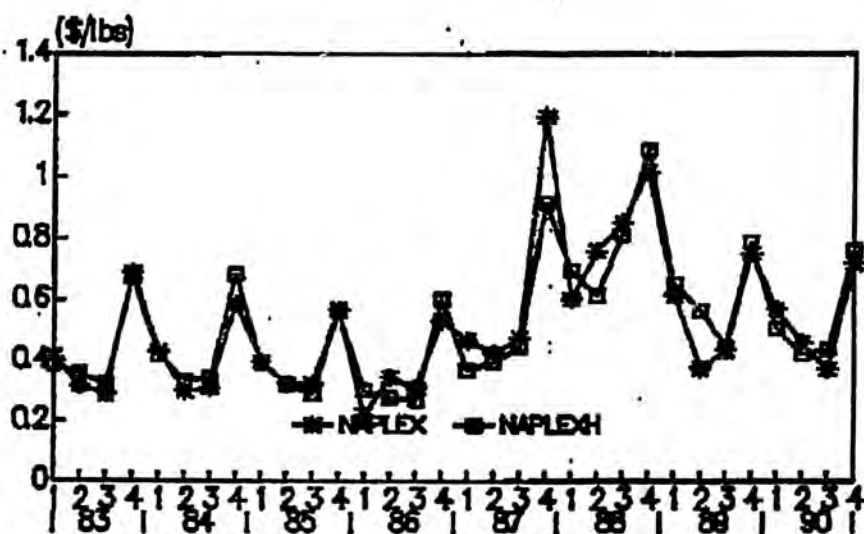


Figure 3. Predicted (NAPLEXH) vs. actual (NAPLEX) North American low-valued salmon Exvessel price (1983 to 1990).

In the low-valued exvessel price equation, the explanatory variables explained 86.5 percent of the variation in the low-valued exvessel price. When data becomes available, Chilean coho and canned tuna will be included as potential substitutes for Alaska salmon products.

Exvessel price flexibilities measure the percentage change in the exvessel price given a one percent change in landings, holding all other variables constant. For an increase in landings, a price-flexibility of greater than one (in absolute terms) suggests that the percentage decrease in price will more than offset the percentage increase in landings. In such cases, increased landings would result in decreased revenues to the fishery. Price flexibilities for this model are calculated at their mean-levels for 1982 to 1990. Price flexibilities are only an approximation of exvessel price adjustments to changes in landings. For example, wholesale prices are held constant in calculating price flexibilities.

Given these data, preliminary estimations of mean-level price flexibilities for salmon at the exvessel level range between -0.60 and -0.85. This means that a one-percent increase in landings results in a 0.60 to 0.85 percent decrease in exvessel price. Thus, the increase in landings in the fishery are partially offset by the price reductions. These price flexibilities are much higher, in absolute values, than those previously found in other studies. This raises the possibility that very high landings in the Alaska salmon fisheries may decrease revenues to the industry (price flexibilities under those circumstances will exceed those calculated at the mean. As landings increase the price flexibility also increases.) This conclusion will hold if, given a high productivity in the fishery, the estimated price flexibility coefficients exceed one. However, the full impact of changes in landings to fishery revenues cannot be ascertained until the full model is simulated.

In bloc 2, all 48 equations have been preliminarily estimated. The correlations between the Alaska exvessel prices by species, gear type, and area, and the appropriate North American exvessel prices were estimated. The correlations were quite high, with the strongest correlations for sockeye and pink salmon. For example, the correlation between Prince William Sound purse seined sockeye salmon and the North American high-valued Pacific salmon exvessel prices was 0.961. Squaring this term gives us a coefficient of determination of 92.4 percent. This means that 92.4 percent of the variation in the Prince William Sound purse seined sockeye salmon is explained by the variation in the North American (Canadian and U.S.) high-valued Pacific salmon exvessel prices. A graphical representation of the fit between the predicted and actual exvessel prices Prince William Sound purse seined sockeye salmon is shown in figure 4. These preliminary results indicate that regional results of the modelling effort should be reliable.

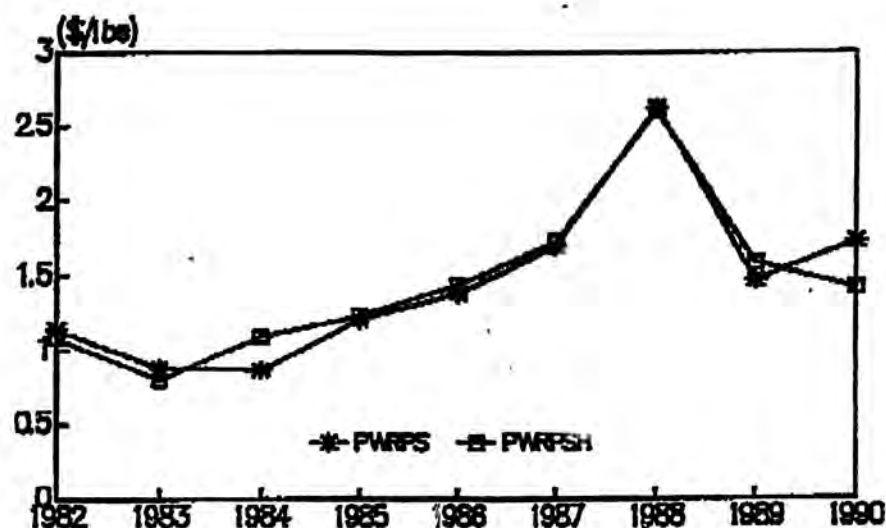


Figure 4. Predicted (PWRPSE) vs. actual (PWRPS) prince William Sound sockeye purse-seined salmon exvessel price (1982 to 1990).

The only unsatisfactory correlations have been for chinook salmon. The low correlations are probably the consequence of a few outliers in the exvessel price data set. In part, this may be a result of chinook not being the target species in several of the regional fisheries. Low chinook landings in these regions allow for the reported exvessel price to be easily distorted by the activities of a single year or few fishery participants. The investigators are awaiting CFEC harvest data, disaggregated by region, to address this problem.

Conclusion

When the entire model is estimated and simulated, the regional Alaska exvessel prices will be forecasted into the future by correlating the regional exvessel prices with the predicted North American exvessel prices. This task will not be completed for several months.

Preliminary results, in comparison to previous studies, indicate that the increased supply of world salmon may have shifted the demand curve for Alaska salmon inward. As one can see from figure 5, this means that to continue selling quantity X, prices would decline to P_1 unless market expansions could shift the demand curve outward again.

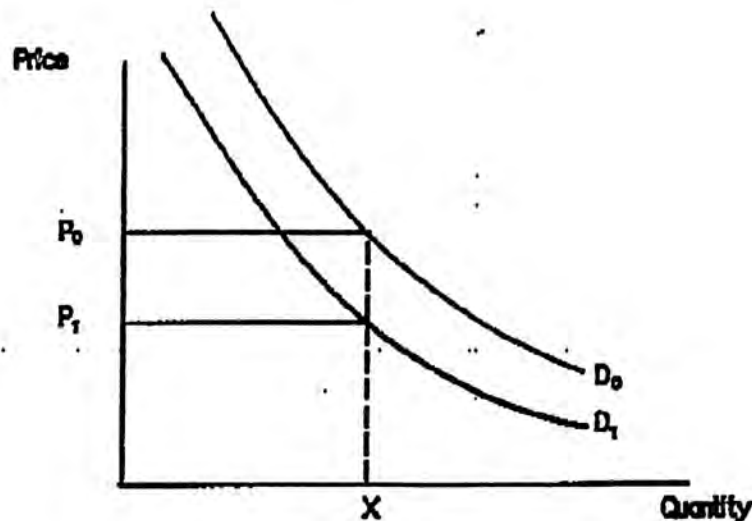


Figure 5. Price effect of an inward shift of a demand curve keeping quantity constant.

This suggests that there is significant downward pressure on Alaska salmon prices in years of high Alaska production. The downward price adjustments are the mechanism through which increased Alaska production is absorbed into the existing world market. However, full simulation results along with more information as to future farmed salmon supply levels and other market conditions, are needed before any conclusions can be drawn as to the course that the hatchery program should take.

Appendix A

Cases to be Simulated

Case 1 - Base Case - the salmon enhancement program continues at currently permitted capacity levels.

Case 2 - The salmon enhancement program continues at state and PNP projected production levels.

Case 3 - The salmon enhancement program is eliminated in FY 83.

Case 4 - Salmon production from enhancement projects is increased/decreased by increments of 15 percent.

Case 5 - The pink salmon program is eliminated and all else remains at the currently permitted capacity level.

Case 6 - The sockeye salmon program is eliminated and all else remains at the currently permitted capacity levels.

Case 7 - Salmon production from pink salmon enhancement projects is increased/decreased by an increment of 15 percent and all else remains at the currently permitted capacity level.

Case 8 - Salmon production from sockeye salmon enhancement projects is increased/decreased by an increment of 15 percent and all else remains at the currently permitted capacity level.

Case 9 - Salmon production from chum salmon enhancement projects is increased/decreased by an increment of 15 percent and all else remains at the currently permitted capacity level.

Case 10 Salmon production from coho salmon enhancement projects is increased/decreased by an increment of 15 percent and all else remains at the currently permitted capacity level.

Case 11 Salmon production from king salmon enhancement projects is increased/decreased by an increment of 15 percent and all else remains at the currently permitted capacity level.

Appendix B**Project Progress Report.**

Below the progress is reported against the timeline reported in the original milestone chart (summarized below).

<u>Area</u>	<u>Description</u>	<u>Targeted Completion Date</u>	<u>Percent Completed</u>
1)	Data Collection and Update of Model	3/92	75
2)	Functional Form Work	3/92	70
3)	Disaggregation work	7/92	80
4)	Canned Salmon Work	6/92	10
5)	Disaggregation of Countries	6/92	90
6)	Elasticity Estimates	7/92	10
7)	Level estimation (market)	7/92	20
8)	Sensitivity Case Analysis	10/92	5
9)	Regional Correlation	8/92	80
10)	Predictions	10/92	0
11)	Sensitivity of 11 cases	10/92	0
12)	SAS program	10/92	10
13)	Final Report	10/92	5
14)	Preliminary Report	4/92	Finished

Overall, the marketing portion project is on schedule. Areas 1 and 2 were to have been the only areas to be fully completed by April. Area 1 is mostly complete, but is still in progress because all the 1991 data is not available. (For example, CFEC salmon exvessel prices will not be fully compiled until August). Area #2 has also been mostly completed but the model is being expanded and fine tuned as additional data becomes available. Progress has been made in all areas except areas 10, and 11 which cannot be performed until the modelling phase is complete.

Appendix C

The Full Model

Bloc One

Norwegian Atlantic

- 1) $NQAE^s = f_1(NPAE, NPAJ, NPAU, QTOTA, EKO_1)$
- 2) $NQAJ^s = f_2(NPAE, NPAJ, NPAU, QTOTA, EKO_2)$
- 3) $NQAE^d = f_3(EPAERT, EPHERT, EPLERT, EKO_3)$
- 4) $NQAJ^d = f_4(JPAJRT, JPHJRT, JPLJRT, EKO_4)$
- 5) $NQAU^d = f_5(UPAJRT, UPHJRT, UPLJRT, EKO_5)$
- 6) $QTOTA = NQAE^s + NQAJ^s + NQAU^s$
- 7) $EPAERT = ((NPAE / NORECU) * ETARIFF) / ECPI$
- 8) $EPAJRT = ((NPAJ / NORJAP) * ETARIFF) / ECPI$
- 9) $EPAURT = ((NPAU / NORUSA) * ETARIFF) / ECPI$
- 10) $NQAE^d = NQAE^s + QSCIR^s$
- 11) $NQAJ^d = NQAJ^s$
- 12) $NQAU^d = NQAU^s$

North American High-Valued Salmon

- 13) $UQHKE^s = f_6(UPHKE, UPHKJ, QTOTH, EKO_6)$
- 14) $UQHJ^s = f_7(UPHKE, UPHKJ, QTOTH, EKO_7)$
- 15) $UHINV = f_8(NPH, QTOTH, EKO_8)$
- 16) $UQHKE^d = f_9(EPHERT, EPLERT, EPAERT, EKO_9)$
- 17) $UQHJ^d = f_{10}(JPHJRT, JPLJRT, JPAJRT, EKO_{10})$
- 18) $UPH = (UPHKE * UQHKE^s + UPHKJ * UQHJ^s) / (UQHKE^s + UQHJ^s)$
- 19) $EPHERT = (UPHERT / USAECU) / (ETARIFF * ECPI)$
- 20) $JPHJRT = (UPHJRT * JAPUSA) / (JSTARIFF * JCPI)$
- 21) $QTOTH = ULANH + UHINV_{t-1}$
- 22) $UQHKE^s = UQHKE^d$
- 23) $UQHJ^s = UQHJ^d$

North American Low-Valued Salmon

- 24) $QTOTLZ = f_{11}(UPL, UPLC, QTOTL, EKO_{11})$
- 25) $QTOTLC = QTOTL - QTOTLC + ULINVC_{t-1}$
- 26) $UQLKE^s = f_{12}(UPLKE, UPLKJ, QTOTLZ, EKO_{12})$
- 27) $UQLKJ^s = f_{13}(UPLKE, UPLKJ, QTOTLZ, EKO_{13})$
- 28) $ULINV = f_{14}(UPL, QTOTLZ, EKO_{14})$
- 29) $UQLKEC^s = f_{15}(UPLKEC, UPLKAC, QTOTLZC, EKO_{15})$
- 30) $UQLKAC^s = f_{16}(UPLKEC, UPLKAC, QTOTLZC, EKO_{16})$
- 31) $ULINVC = f_{17}(UPLC, QTOTLC, EKO_{17})$
- 32) $UQLKE^d = f_{18}(EPHERT, EPLERT, EPAERT, EKO_{18})$
- 33) $UQLKJ^d = f_{19}(JPHJRT, JPLJRT, JPAJRT, EKO_{19})$
- 34) $UQLKEC^d = f_{20}(EPLERT, EKO_{20})$
- 35) $UQLKAC^d = f_{21}(APLACRT, EKO_{21})$
- 36) $UPL = (UPLKE * UQLKE^s + UPLKJ * UQLKJ^s) / (UQLKE^s + UQLKJ^s)$
- 37) $UPLC = (UPLKEC * UQLKEC^s + UPLKAC * UQLKAC^s) / (UQLKEC^s + UQLKAC^s)$
- 38) $EPLERT = (UPLERT / USAECU) / (ETARIFF * JCPI)$

399 JPLJRT = (UPLJRT * JAPUSA)/(ITABRT * ECPJ)
 400 EPLBORT = (UPLBORT /USABCU)/(ETABRT * JCEJ)
 411 AFLACRT = (UPLACRT * AUSUSA)/(ACPI)
 422 GTOPL = ULANL + ULINVL-1
 431 UGLXB⁸ = UGLXB^d
 441 UGLXB⁸ = UGLXB^d
 451 UGLXB⁸ = UGLXB^d
 461 UGLXB⁸ = UGLXB^d

North American Reversed Price Equations

471 NAPHREX = $\frac{1}{2}$ (UPH, UPL, TSUPE, UPAU, EKO22)
 481 NAPLEX = $\frac{1}{2}$ (UPL, UPH, TSUPE, UPAU, EKO23)
 491 UPAU = (NPAU * USABCU)

Endogenous Variables (Block 1)

NOAB⁸, NOAJ⁸, NOALT⁸, NOABP^d, NOALP^d, NOALP^d, NPAK, NPAJ, NPAU, EPARKT,
 JPAURT, UPAURT UGLXB⁸, UGLXB^d, ULINV, UGLXB^d, UGLXB^d, UPH, UPHKE,
 UPHXJ, EPHERT, JPHJRT, GTOH GTOPL, GTOPLZ, GTOPL, UGLXB⁸, UGLXB^d,
 ULINV, UGLXB⁸, UGLXB^d, ULINVC, UGLXB^d, UGLXB^d, UGLXB^d, UGLXB^d, UGLXB^d,
 UPLKE, UPLXJ, UPLXBC, UPLXAC, UPL, UPLC, EPLERT, JPLJRT, EPLBORT, AFLACRT,
 NAPHREX, NAPLEX, UPAU

Block Two

Alaska Reversed Price Correlations

501 FWRDGG = (NAPHREX, C)
 511 FWRDGG = (NAPHREX, C)
 521 FWRDGG = (NAPHREX, C)
 531 FWRDGG = (NAPHREX, C)
 541 FWRDGG = (NAPHREX, C)
 551 FWRDGG = (NAPHREX, C)
 561 FWRDGG = (NAPHREX, C)
 571 FWRDGG = (NAPHREX, C)
 581 FWRDGG = (NAPHREX, C)
 591 FWRDGG = (NAPHREX, C)
 601 FWRDGG = (NAPHREX, C)
 611 FWRDGG = (NAPHREX, C)
 621 FWRDGG = (NAPHREX, C)
 631 FWRDGG = (NAPHREX, C)
 641 FWRDGG = (NAPHREX, C)
 651 FWRDGG = (NAPHREX, C)
 661 FWRDGG = (NAPHREX, C)
 671 FWRDGG = (NAPHREX, C)
 681 FWRDGG = (NAPHREX, C)
 691 FWRDGG = (NAPHREX, C)
 701 FWRDGG = (NAPHREX, C)
 711 FWRDGG = (NAPHREX, C)
 721 FWRDGG = (NAPHREX, C)
 731 FWRDGG = (NAPHREX, C)
 741 FWRDGG = (NAPHREX, C)
 751 FWRDGG = (NAPHREX, C)

76) KORPS = (NAPHEX, C)
 77) KOSPS = (NAPHEX, C)
 78) KOCPS = (NAPLEX, C)
 79) KOPPS = (NAPLEX, C)
 80) KOKSN = (NAPHEX, C)
 81) KORSN = (NAPHEX, C)
 82) KOSSN = (NAPHEX, C)
 83) KOCSN = (NAPLEX, C)
 84) KOPSN = (NAPLEX, C)
 85) JURHT = (NAPHEX, C)
 86) JURHT = (NAPHEX, C)
 87) JUSHT = (NAPHEX, C)
 88) JUCHT = (NAPLEX, C)
 89) JUPHT = (NAPLEX, C)
 90) JURPT = (NAPHEX, C)
 91) JURPT = (NAPHEX, C)
 92) JUSPT = (NAPHEX, C)
 93) JUCPT = (NAPLEX, C)
 94) JUPPT = (NAPLEX, C)

Variable Names

(Note, a more thorough definition of the variable names can be found in the full report.)

Endogenous Variables: (bloc 1)

NQAE⁰ = the quantity of Norwegian farmed Atlantic salmon exported to the EEC.
 NQAJ⁰ = the quantity of Norwegian farmed Atlantic salmon exported to Japan.
 NQAU⁰ = the quantity of Norwegian farmed Atlantic salmon exported to the U.S.
 NQAEJ¹ = the per capita quantity of imported Norwegian, Scot, and Irish farmed Atlantic salmon in the EEC.
 NQAJE¹ = the per capita quantity of imported Norwegian Atlantic salmon in Japan.
 NQAUJ¹ = the per capita quantity of imported Norwegian Atlantic salmon in the United States.
 NPAE = the Norwegian price of Norwegian farmed Atlantic salmon exported to the EEC.
 NPAJ = the Norwegian price of Norwegian farmed Atlantic salmon exported to Japan.
 NPAU = the Norwegian price of Norwegian farmed Atlantic salmon exported to the United States.
 EPAERT = the "real" after tariff price of Norwegian farmed Atlantic salmon in the EEC.
 JPAJRT = the "real" after tariff price of Norwegian farmed Atlantic salmon in Japan.
 UPAURT = the "real" after tariff price of Norwegian farmed Atlantic salmon in the United States.
 UGHKE⁰ = the quantity of North American exports of high-valued salmon to the EEC.
 UGHLE⁰ = the quantity of North American exports of high-valued salmon to Japan.
 UHINV = the ending inventory of North American high-valued salmon.
 UGHKE¹ = the quantity of EEC imports of North American high-valued salmon.
 UGHLE¹ = the quantity of Japanese imports of North American high-valued salmon.
 UPH = the North American weighted average export price of high-valued salmon.
 UPEKE = the North American export price of high-valued salmon.
 UPELE = the North American export price of high-valued salmon.
 EPHERT = the "real" after tariff price of North American high-valued Pacific salmon in the EEC.
 JPHERT = the "real" after tariff price of North American high-valued Pacific salmon in Japan.
 QIOTH = the North American total available supply of high-valued salmon.
 QIOTL = the North American total available supply of low-valued salmon.
 QIOTLZ = the North American total available supply of fresh/frozen low-valued salmon.
 QIOTLC = the North American total available supply of canned low-valued salmon.
 UGLE⁰ = the quantity of North American exports of low-valued salmon to the EEC.

UGLXJ³ = the quantity of North American exports of low-valued salmon to Japan.
 ULINV = the ending inventory of North American low-valued salmon.
 UGLKEC³ = the quantity of North American exports of low-valued canned salmon to the EEC.
 UGLKAC³ = the quantity of North American exports of low-valued canned salmon to Australia and N.Z.
 ULINVO = the ending inventory of North American low-valued canned salmon.
 UGLKEC⁴ = the quantity of EEC imports of North American low-valued salmon.
 UGLXJ⁴ = the quantity of Japanese imports of North American low-valued salmon.
 UPL = the North American weighted average export price of low-valued salmon.
 UGLKEC⁴ = the quantity of EEC imports of North American low-valued canned salmon.
 UGLKAC⁴ = the quantity of Japanese imports of North American low-valued canned salmon.
 UPLC = the North American weighted average export price of low-valued salmon.
 UPLKE = the North American export price of low-valued salmon exported to the EEC.
 UPLJW = the North American export price of low-valued salmon exported to Japan.
 UPLKEC = the North American export price of low-valued canned salmon exported to the EEC.
 UPLKAC = the North American export price of low-valued canned salmon exported to Australia and N.Z.
 EPLERT = the "real" after tariff price of North American low-valued Pacific salmon in the EEC.
 JPLJRT = the "real" after tariff price of North American low-valued Pacific salmon in Japan.
 EPLECRT = the "real" after tariff price of North American low-valued can Pacific salmon in the EEC.
 APLACRT = the "real" after tariff price of North American low-valued can Pacific salmon in Australia and N.Z.
 NAPHEK = the North American exvessel price of high-valued salmon.
 NAPLEX = the North American exvessel price of low-valued salmon.
 UPAU = the price of Norwegian farmed Atlantic salmon in North America.

Exogenous Variables: (bloc 1)

EXO_i = indicated exogenous factors to be included in equation 1.
 NORECU = the Norwegian kroner/ECU exchange rate.
 NORJAP = the Norwegian kroner/yen exchange rate.
 NORUSA = the Norwegian kroner/U.S. dollar exchange rate.
 USAECU = the U.S. dollar/ECU exchange rate.
 JAPUSA = the yen/U.S. dollar exchange rate.
 AUUSA = the Australian dollar/U.S. dollar exchange rate.
 ECPI = the EEC consumer price index for food.
 UCPI = the U.S. consumer price index for food.
 JCPI = the Japanese consumer price index for food.
 ACPI = the general Australian consumer price index for food.
 JTARRIF = The Japanese tariff rate on fresh/frozen salmon.
 ETARRIF = The EEC tariff rate on fresh/frozen salmon.
 QSCIR = the quantity of Scottish and Irish farmed Atlantic salmon.

Endogenous Variables: (bloc 2)

PWKPS PWSPS PWRPS PWCPS PWPPS is the exvessel price in the Prince William Sound purse seine fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

PWKDG PWSDG PWRDG PWCDG PWPDG is the exvessel price in the Prince William Sound drift gill fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

CIKPS CISPS CIRPS CICPS CIPPS is the exvessel price in the Cook Inlet purse seine fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

CIKPS CISPS CIRPS CICPS CIPPS is the exvessel price in the Cook Inlet drift gill fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

CIRSN CISSN CIRSIN CICSIN CIPSN is the exvessel price in the Cook Inlet set net fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

KOKPS KOSPS KORPS KOCPS KOPPS is the exvessel price in the Kodiak purse seine fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

KOKSN KOSSN KORSN KOC SN KOPSN is the exvessel price in the Kodiak set net fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

JUKHT JUSHT JURHT JUCHT JUPHT is the exvessel price in the Kodiak hand troll fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

JUKPT JUSPT JURPT JUCPT JUPPT is the exvessel price in the Kodiak power troll fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

NAPHEX = the North American exvessel price of high-valued salmon, measured in U.S. dollars per pound.

NAPLEX = the North American exvessel price of low-valued.

Exogenous Variables: (bloc 2)

C: A constant.

***Economic Review of the Salmon
Enhancement Program:
Emphasis on the Price Responsiveness of Alaska
Salmon to Enhancement Production***

Introduction

In May 1991, the Senate Special Committee on International and Domestic Fisheries initiated an extensive review of the Alaska salmon hatchery and enhancement program. As a result of considerable interest in the project, participation in the Hatchery Research Project includes representatives from both the Senate and the House of Representatives. The purpose of the study is to 1) review the history and legislative intent of the enhancement program, 2) analyze the current status of the program, and 3) consider future options for the program--ranging from fine tuning to possible redirection.

As part of the Hatchery Research Project, an Economics and Marketing study group was developed to provide information to the legislature on the economic impacts of salmon hatchery production. The group is to help determine

- if the current levels of Alaska salmon harvests are over-or under-supplied from a world-market perspective and
- if increased hatchery production of salmon will lower prices, fishing and processing revenues, and the total net value of Alaska's salmon fisheries.

To address these public policy questions requires a benefit-cost analysis. This type of analysis measures the level and cost of enhanced salmon production, the cost of managing, harvesting, and processing enhanced salmon stocks, and the impact or "price responsiveness" of world salmon markets to various levels of Alaska enhanced salmon production. The costs are then subtracted from the benefits to estimate the net benefits of the salmon enhancement program and the incremental net benefits of different levels of enhanced salmon production to commercial fisheries. To analyze only the impact of different levels of salmon production on world salmon markets and prices paid to fishermen is insufficient for thorough policy analysis because it does not measure the net benefits (benefits minus costs) of the commercial salmon fisheries to fishermen or all Alaskans.

An example of some of the policy questions a benefit-cost analysis would help to address are as follows:

- Is increased Alaska salmon hatchery production the cause of this year's lower salmon prices? What is the significance of other factors, such as increased farmed-salmon production, exchange rates, economic recessions, and prices of food substitutes?

What is the most profitable salmon species mix and level of production for the statewide enhancement program? Should the emphasis shift from pink salmon to king and coho salmon, for example, or even to other non-salmon species?

If Alaska curtailed hatchery salmon production, would Alaska salmon (both wild and hatchery) prices increase or would the resulting market share be filled by farmed salmon from other countries? Ultimately, what would be the net effect or benefits to Alaskans from these changes?

How are the estimated benefits and/or costs of the existing hatchery production distributed to fishermen and processors in each region of the state? If changes in production occurred, how would these benefits and/or costs be distributed?

What would be the economic benefits of changes in policy or additional legislative oversight regarding the production capacity and releases of hatchery salmon?

Need for Additional Research

Rather than initiating a new benefit-cost analysis, the Senate Special Fisheries Committee requested the Hatchery Research Group to first identify the specific issues that need additional economic research. In response, the economics group developed a study plan with the initial tasks of reviewing economic and marketing studies completed to date and assessing the need for additional research.

After reviewing current research, the group determined that insufficient economic information currently exists to accurately address salmon enhancement public policy questions. The research that has been completed is either out-of-date, or additional research needs to be done to improve the reliability of existing economic models. As a result of the significant investment by private parties and the state of Alaska in both enhancement projects and commercial fishing, a rigorous analysis using accepted bioeconomic techniques is warranted to fill these information gaps.

Based on our review, the economics group proposed a set of contracts for additional research. The group worked closely with staff from the Alaska Department of Fish and Game (ADF&G), FRED Division to develop the research plan because FRED Division staff have considerable experience in these areas of research and have contracted for previous studies. In addition, we solicited comments from the Divisions of Commercial Fisheries and Sport Fish to ensure that their concerns are addressed. As the committee requested, the studies build on previous research to close information gaps. Funding for the research contracts was approved at the November 1 Legislative Council meeting.

Research Components

The five principal research components are:

- 1) a hatchery production and cost model,
- 2) a fish population model linked to fishing effort and harvests,
- 3) a demand model for Alaska salmon in world markets,
- 4) a fishing cost model, and
- 5) a computer software system to combine the four models.

The five components are described below including estimated costs and a brief summary of the information gaps the research is intended to address. Based on prior research conducted for the FRED Division and expertise, the economics group contacted potential University of Alaska researchers to determine interest in the projects.

As a result of the short time period available to complete the research, it will be funded through RSAs. Therefore, interested parties did not formally bid on the projects, but instead provided information on proposed research methodology, pertinent research experience and qualifications, and the ability to complete the contract in the time available.

Hatchery Cost and Production Model

Principal Investigators: Economics Group, Legislative Research Agency, and the ADF&G, FRED Division staff

Anticipated Cost: \$0

This research component consists of a survey of hatchery and enhancement project operators to determine the cost of producing salmon. In economics jargon, survey information will be used to develop an enhancement project "production function" to estimate the incremental cost of changes in the number of salmon produced by these projects. The survey will be developed by the economics group and FRED division staff and administered by the Legislative Research Agency and FRED division. This portion of the research will also solicit information from the ADF&G, Division of Commercial Fisheries regarding the costs of fisheries management of enhancement project stocks. This portion of the research needs to be conducted because no data exist on the incremental costs of enhancement project fish production. When the Governor's fisheries mini-cabinet reviewed the Alaska salmon enhancement program in 1984, a similar survey was conducted. Those results, however, are out-dated and additional salmon enhancement projects have been developed since that time.

Biological Population Model

Principal Investigators: Dr. Jeremy Collie, Juneau Center for Fisheries and Ocean Sciences, University of Alaska Fairbanks

Anticipated Cost: \$10,000

The purpose of the biological population model is to estimate the number of adult fish produced by enhancement projects and available for harvesting. Salmon produced by hatcheries and other projects are exposed to similar biological and environmental conditions and fisheries as wild stocks--as compared to farmed salmon. As a result, this research would estimate the interdependence of wild and enhanced stocks. These estimates will be taken into consideration varying management assumptions regarding stock separation and cost recovery. This research component is necessary because ADF&G has not comprehensively analyzed the interaction of wild and enhanced stocks and the impact of different levels of enhanced stock production on commercial fisheries harvests.

Salmon Demand Model

Principal Investigator: Dr. Mark Herrmann, Department of Economics, and Dr. Joshua Greenberg, School of Land Resources Management, University of Alaska Fairbanks

Anticipated Cost: \$18,000

This contract will extend and improve research on the salmon enhancement program completed to date by Dr. Boyce for the FRED division. To more fully understand world salmon markets, improvements to existing demand models are needed. Relatively little research has been conducted to date on the demand for Alaska salmon, and models that do exist are insufficient to reliably answer the Legislature's policy questions. The additional work has not been contracted by the FRED because of insufficient funding.

In 1990, Dr. John Boyce's research compared single-equation and system of equations demand models for Alaska salmon. The study compared two, single-equation models developed by Ben Muse of the Alaska Commercial Fisheries Entry Commission (CFEC) in 1984 and Nick Ronan, University of Alaska Anchorage, Institute for Social and Economic Research (ISER) in 1989, and an alternative model proposed by Hongru Zhang, University of Alaska Fairbanks graduate student, using a Two-Stage-Least-Squares (2SLS) approach. Boyce found that the 2SLS approach appears to have superior predictive capability within the sample.

Boyce (1990) estimates ex-vessel and wholesale prices for five species of Pacific salmon, which is required for evaluating enhancement project tradeoffs between different salmon species and markets that are relevant to the state of Alaska. However, Boyce's study did not (1) develop a satisfactory profit function at the wholesale level for all salmon species, (2) conduct a full testing of wild, enhanced, and farmed salmon substitutes, including the extent to which farmed-salmon production is a substitute for Alaska salmon harvests, (3) link ex-vessel

markets or wholesale markets to retail consumer markets, and (4) produce demand models for pink and sockeye salmon with low estimation errors.

In addition to this recently completed research by Dr. Boyce, recent econometric analyses completed by Lin and Herrmann (1988) and Mittelhammer, Herrmann, and Lin (1989) provide considerable information on the import and export markets for salmon, and the relationship of farmed-salmon markets to capture-fishery markets.

The models of Mittelhammer, Herrmann, and Lin develop demand functions using import and export data closer to the final markets. They include more substitutes, and incorporate a supply and demand model for farmed salmon. However, the models are not sufficiently stratified by species at the ex-vessel level for evaluating tradeoffs in Alaska's statewide enhancement program.

Neither of the two modeling efforts (Boyce or Mittelhammer, Herrmann, and Lin) were designed to compute regional distribution of gross earnings within the major Alaska salmon fisheries, or the amount of price response imposed on a given region by another region's salmon production. The ability to discern regional impacts is a high priority in evaluating the benefits and costs of the salmon enhancement program.

In summary, two major salmon demand model improvements are needed. The first is in the ability to project future salmon prices and the impact of changes in enhanced salmon production and harvest levels on Alaska salmon prices. The second improvement is incorporating into salmon demand models the impact of changes in world salmon-farming production levels on Alaska salmon markets and prices.

Fishing Cost Model

Principal Investigator: Dr. John Boyce, Department of Economics, University of Alaska Fairbanks

Anticipated Cost: \$20,000

This portion of this study will estimate the cost to fishermen of harvesting salmon to determine the incremental cost of harvesting different levels of enhancement project produced fish. This information can address questions such as--if hatchery production results in a 10 percent increase in harvest levels and a 2 percent decrease in the price of pink salmon, are the additional revenues minus the additional cost of harvesting the fish sufficient to increase fishermen's net revenues.

The objective of this study is to formulate and test empirical models that will project short- and long-run fishing costs for specific Alaska salmon fisheries. To conduct a benefit-cost analysis, fishing costs must be determined in the short and long run. In the short run, an enhancement project or a management action may encourage salmon fishermen to direct more fishing effort--which is a function of gear, boat size, horse power, and crew size, for example--into a specific statistical area and away from another statistical area (or alternative fishing opportunity). With the existing management constraints on salmon fishing in

place, such as limited entry and fisheries openings and closures, the short-run increases in marginal costs may be smaller or larger than the potential short-run revenues from a given project. However, in the long run, fishermen can be expected to increase fishing effort in statistical areas where the marginal revenues are greater than marginal costs of fishing. Fishing effort would be increased even if new vessels are not allowed to enter the fishery. As a result of insufficient research, economists currently can only provide informed guesses of the magnitude of these short- and long-run fishing costs in Alaska's salmon fisheries. Because little extensive or reliable research has been completed on this topic which accounts for the relatively higher cost of this study component.

Combining of Models

Principal Investigator: Drs. John Boyce and Mark Herrmann, Department of Economics, and Dr. Diane Bischak, School of Management, University of Alaska Fairbanks

Anticipated Cost: \$10,000

When completed, the four models will be combined into a single, complete software system for the analysis of specific policy questions. This contract will test specific future enhancement program options--such as maintaining, decreasing, or increasing current enhanced salmon production levels, changing the current species mix, and maintaining or changing the location of enhancement projects--on the net economic benefits to fishermen and Alaskans. To the extent possible the analysis will differentiate the distribution of enhancement program net benefits among regions of the state. The results of this analysis will be a written report for the committee that will facilitate the development of public policy decisions.

Conclusion

In addition to providing information on Alaska's salmon enhancement programs, the models developed by the study could be used for evaluating other salmon management policy questions.

The total estimated cost of the research is \$58,000 which is approximately \$17,000 less than the UAA, Institute of Economic and Social Research proposal provided in May 1991. The reasons for the estimated lower costs are that the hatchery cost model work would be done with current legislative and ADF&G staff.

The research does not include studies to develop new markets or products for Alaska salmon for a number of reasons. The time available is insufficient, the cost of reliable marketing studies is usually quite high, and the Alaska Department of Commerce and Economic Development (DCED), Division of Economic Development and the Alaska Seafood Marketing Institute (ASMI) are both initiating salmon marketing studies in response to this summer's lower salmon prices. Therefore, the legislative economics and marketing group plans to provide

information to the legislature on the success of past state efforts to market Alaska salmon and coordinate with the DCED efforts to avoid research duplication and encourage the best possible information.

The research also does not include studies to estimate the net benefits of the salmon enhancement program to sport or subsistence users. Including these additional uses would significantly expand the scope and cost of the studies.

November 30, 1991

Ginny Fay

ALASKA STATE LEGISLATURE SENATE

SENATOR RICHARD I. ELIASON

PRESIDENT OF THE SENATE
LABOR & COMMERCE COMMITTEE
RESOURCES COMMITTEE
RULES COMMITTEE
CHAIRMAN, SPECIAL COMMITTEE ON
DOMESTIC & INTERNATIONAL
COMMERCIAL FISHERIES



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July 16, 1992

Dave Houseworth, Manager
Tamgas Creek Hatchery
Metlakatla Indian Community
P.O. Box 410
Metlakatla, AK 99926

Dear Mr. Houseworth:

We would like to thank you for the time and effort you have invested in responding to the survey of **intensively** modeled enhancement projects sent to you as part of the Legislative Enhancement Program Review Project. The contractor for the salmon population modeling research is using the survey data to complete that aspect of the study.

Enclosed is the last survey portion of the project; we would again like your assistance by completing two additional forms (enclosed). The first form is the **Salmon Enhancement Project production survey** for the non-intensively modeled projects. This pink survey form is shorter and simpler than the survey form for more intensively modeled enhanced fisheries which you have already completed.

There are three primary reasons for modeling some of the enhancement projects less intensively--1) enhanced production is a relatively small portion of a particular fishery's commercial harvest, 2) Alaska Department of Fish and Game (ADF&G) data are insufficient for more extensive modeling efforts, and 3) the scope of the review project does not allow intensive population modeling of all enhanced fisheries.

As with the more intensively modeled production survey, a separate survey form is included for each "project." The first page of each production survey has been partially completed based on ADF&G, FRED Division staff identification of salmon enhancement projects. If you have any

July 16, 1992

Page 2

corrections to the project name or other identifying data, or if there are additional projects not included in the surveys provided, please make the appropriate corrections or additions. Blank forms are attached.

The second (blue) form is a cost-of-production survey for each facility identified under FACILITY NAME in the SALMON ENHANCEMENT PRODUCTION SURVEY. This form is called the **FACILITY OPERATING, CONSTRUCTION, AND MANAGEMENT COST SURVEY** and is designed to be similar to budget forecasting that your facility probably does for any upcoming fiscal year. Only one of these production cost survey forms is to be completed for each facility. You also should not adjust any future costs for inflation.

It is important to note that in completing the one production cost survey form for your facility that "years" in this form refers to state fiscal years (July 1 - June 30) while the production surveys refer to calendar years. However, if your fiscal year does not begin on July 1, please indicate the starting date on your survey form.

There are some special hypothetical production cost cases in the survey that will require you to project costs for production levels that may not be likely or feasible for your facility's operations. For example, question four asks you to estimate how your production costs would change if a portion of your production was excluded. These hypothetical cases are necessary to create a mathematical model of operating and construction costs for the statewide enhancement program, which allows the computation of costs of production levels not included in the survey. These cases will only be analyzed in aggregate and will not be used to determine benefits and costs of individual hatchery outputs.

Operating and construction costs for some increased production scenarios are also requested in the survey form. These production increases are combined together by species (not projects) while production survey forms have been completed on a project basis. Some facilities will have more than one project and release location for a given species; this may cause some confusion in determining how to apportion these costs between projects. In these cases, the total incremental production costs (for the 15 percent increase scenario) should be estimated for the most likely and efficient combination of production from each project that would result in

the increased production. For all of the hypothetical cases in questions 4 and 5, the total annual costs for a facility should be entered on the survey form rather than the estimated change in annual costs. For example:

Two sockeye projects (Project 1 and Project 2) are carried out at Facility Z. Together they produce 20,000 sockeye harvests in 1996 and are projected to produce 30,000 harvests in 1999 to 2021.

Increased production of Project 1 for sockeye salmon (producing harvests of 10,000 fish in 1996 from smolt releases in previous years) would be difficult to increase by 15 percent without some radical changes in operation or new construction.

On the other hand, Project 2 also produces 10,000 harvested fish in 1996 but fry releases could easily be increased to 15 percent of the total sockeye production of 20,000 harvested fish ($20,000 \times 1.15 = 23,000$ fish from Project 2). Thus, costs for the increase production should be estimated for Project 2, the most likely source of increased production in this example.

For the 15 percent incremental increased production scenario, it may not be possible to increase production for a particular species in your facility. If there is simply no way to do this without adding a new project, leave the associated 15 percent production case blank for that species but note why you could not carry it out on the form.

Finally, the cost projections for the 15 percent production level increase should be based upon obtaining the increased harvests in one single salmon life cycle or as nearly as possible to that time interval.

The completed survey forms need to be sent to Steve McGee at the ADF&G, FRED Division Headquarters Office by June 15, 1992. There will undoubtedly be questions about how to fill out the survey. Please address these to Jeff Hartman or Steve McGee, ADF&G, 465-4160.

July 16, 1992
Page 4

Again, thank you for your time and cooperation.

Sincerely,



Senator Dick Eliason
Senate President

Jeff Koenings, Director
Division of FRED

ALASKA STATE LEGISLATURE SENAT

SENATOR RICHARD I. ELIASON

PRESIDENT OF THE SENATE
LABOR & COMMERCE COMMITTEE
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July 16, 1992

Frank Thrower, Manager
Little Port Walter Research Station
c/o NOAA, NMFS
Auke Bay Laboratory
11305 Glacier Highway
Juneau, AK 99801

Dear Mr. Thrower:

We would like to thank you for the time and effort you have invested in responding to the survey of **intensively** modeled enhancement projects sent to you as part of the Legislative Enhancement Program Review Project. The contractor for the salmon population modeling research is using the survey data to complete that aspect of the study.

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July 16, 1992

Page 2

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Operating and construction costs for some increased production scenarios are also requested in the survey form. These production increases are combined together by species (not projects) while production survey forms have been completed on a project basis. Some facilities will have more than one project and release location for a given species; this may cause some confusion in determining how to apportion these costs between projects. In these cases, the total incremental production costs (for the 15

July 16, 1992

Page 3

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the increased production. For all of the hypothetical cases in questions 4 and 5, the total annual costs for a facility should be entered on the survey form rather than the estimated change in annual costs. For example:

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July 16, 1992
Page 4

Again, thank you for your time and cooperation.

Sincerely,



Senator Dick Eliason
Senate President

Jeff Koenings, Director
Division of FRED

FACSIMILE TRANSMITTAL SHEET

FROM: J. Boyce

**SCHOOL OF MANAGEMENT
UNIVERSITY OF ALASKA, FAIRBANKS
101 BUNNELL BLDG.
FAIRBANKS, ALASKA 99775**

TELEPHONE: (907) 474-7461

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John A. Lehman, Acting Dean

TRANSMITTED TO: Ginny Fay
Legislative Research Assistant

DATE: 11/10/92

TIME: 1:30

PAGES: 8

MESSAGES:

THANK YOU!!

612465

**A BENEFIT-COST ANALYSIS
OF THE
ALASKA SALMON HATCHERY PROGRAM**

EXECUTIVE SUMMARY

John Boyce*, Mark Herrmann*, Diane Bischof, and Joshua Greenberg*****

***Department of Economics
University of Alaska Fairbanks
Fairbanks, Alaska 99775**

****Department of Business Administration
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Fairbanks, Alaska 99775**

*****School of Agriculture, Land and Resource Management
University of Alaska Fairbanks
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A Report to the Legislature of the State of Alaska

November, 1992

A BENEFIT-COST ANALYSIS OF THE ALASKA SALMON HATCHERY PROGRAM

EXECUTIVE SUMMARY

Introduction

The hatchery program in Alaska was created in the early 1970's. At that time, Pacific salmon dominated the world salmon markets. Since then, there has been a rapid rise in the supply of salmon. In Alaska, this has been in large part due to production from the hatchery program. However, the increase in production has been worldwide, and it appears that supplies of salmon on the world market are more likely to continue to increase than to decrease. Given this backdrop, the Legislature of the State of Alaska asked for a cost-benefit analysis of the state-funded hatchery program. This report summarizes the findings of that study.

Since the hatchery program is funded entirely within Alaska, we considered only the interests of the state in our analysis. This means, for example, that benefits to consumers either in the U.S. or in other world markets were ignored completely because they are not benefits that are captured by the state. The benefits to the state were measured by two variables. The net benefits to the fishermen from the hatchery program is the *producer's surplus*, which is the return to fishermen above their fishing costs. The cost of producing the surplus benefits to the fishermen is the cost of running the hatchery program. The net benefits to the state is the net benefits to the fishermen minus the costs of operating the hatchery program.

The study consisted of four parts. First, a biological model (Colle, 1992) was used to estimate the returns of catchable fish 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. Finally, a survey of the hatcheries revealed the costs of producing various levels of hatchery fish.

Research objectives

The request for proposals outlined seventeen alternatives to consider. These management alternatives are described in the first column of Table One. Each management plan was to be considered over a 15- and a 30-year planning horizon. Given the trends in demand and supply as suggested by the events over the past several decades, we have a rough idea of the direction in which the fishery is heading. Our estimates are likely to be very inaccurate within particular years, but should, on average, capture the trend. Since we were asked to conduct a cost-benefit analysis of the hatchery program over a long lifetime, the trend will be much more important than specific yearly predictions.

Comparison of Alternatives

Our calculations suggest that two alternatives dominate all other alternatives in producing net economic benefits to the state. These alternatives are Alternative 3, elimination of the entire hatchery

program, and Alternative 5, elimination of the entire pink salmon program. In addition, we find that the next best alternative is a reduction of the entire program by 15%. However, the order of magnitude difference between a reduction of 15% and eliminating all of the pink salmon program is over \$350 m. over thirty years (undiscounted) and the difference between a 15% reduction and eliminating the entire program is over \$500 m. over thirty years. These numbers suggest that large decreases in either the entire hatchery program, or at least in pink salmon, are warranted.

The differences in total net benefits to the state cannot be explained by catch and revenue data alone. Elimination of any portion of the program causes catch to decrease. Depending upon the species, a reduction in catch may actually increase revenues. However, the gain in net benefits is generally not due to a gain in revenues but to a decrease in costs of running the hatchery program.

Under the current production levels, to produce \$4,260 b. in producer's surplus over the next thirty years, the state spends \$859 m. in hatchery costs, for a net benefit of \$4,001 b. When changes in the hatchery costs are taken into account in addition to the changes in the producer's surplus, each elimination alternative provides a larger net benefit than the current or planned output levels. Furthermore, the net effect by region shows that each region also gains where either pink or red salmon are eliminated (with the exception of Cook Inlet, which loses if either reds or pinks decrease, and Kodiak, which loses if red salmon is eliminated). The biggest surprise in this result is our finding that when hatchery costs are included, Prince William Sound also gains in net by eliminating each of the programs. Thus if the hatchery program were to be financed entirely within the region, the best alternative to Prince William Sound would be to eliminate the hatchery program given that the hatchery programs are eliminated throughout the state.

The net benefit figures in each row of Table One are the returns for each region given that all regions are following the same hatchery production alternative. That is, for the region to get the estimated net benefits listed for a particular alternative, every region has to be following the same alternative.

Hatchery Costs and Net Benefits by Species

We also calculated the cost of producing a pound of salmon from the hatchery program and compared that with the net benefits we estimate fishermen to get on average from a pound of salmon. Our estimates are averaged over the entire state, so there may be substantial regional differences. However, our estimates suggest that for most species, the cost of producing a pound of salmon is greater than the net benefit that pound of salmon provides to fishermen. Table Two presents our estimate of the cost and benefit of a pound of salmon estimated from the 15% increase and decrease alternatives (thus there are two estimates in each case).

In Table Two, we calculate the change in producer's surplus resulting from either an increase or decrease in the quantity of salmon produced by the hatcheries. Our numbers suggest that on average, each pound of pink salmon provides between 5.3 and 6.6 cents of producer's surplus to fishermen. Our estimate of the cost per pound to produce a pound of hatchery raised pink salmon is between 5.6 and 10.8 cents per pound. Thus it appears that the cost per pound of producing pink salmon by hatchery production is greater than the producer's surplus it generates to fishermen.

This result seems to be true of red salmon also. Our estimate of the cost per pound to raise red salmon in hatcheries ranged from 22.1 to 34.6 cents per pound. However, our estimate of the average producer's surplus gained by this production is only 14.2 to 15.4 cents per pound. Before too much emphasis is placed in these numbers, however, it must be mentioned that our estimate of producer's surplus for red salmon is mainly from Bristol Bay (recorded as Western Alaska in our tables). Our estimates for producer's surplus for Bristol Bay were made using average data from similar fisheries

elsewhere in the state. We have no way of knowing how accurate these predictions are given that they are extrapolating well beyond the data available from fisheries elsewhere in Alaska.

Chum salmon also appears to have hatchery production costs that are roughly equal to the producer's surplus generated by an extra pound produced. We estimate that it costs between 8.5 and 9.3 cents to produce another pound of hatchery raised chum salmon, but fishermen receive producer's surplus of only about 9.5 to 10.4 cents per pound.

Coho is similar. Coho are estimated to cost between 27.2 and 40.7 cents per pound to produce, but generate producer's surplus on the order of between 32.3 and 36.0 cents per pound.

King salmon may be the best bet. If the marginal cost of king salmon based on an increase of 15% is accurate, then the cost of a king salmon is estimated to be about 29.7 cents per pound. Our estimate of the return in producer's surplus per pound of king salmon is between 82.8 and 85.7 cents per pound. However, if the marginal cost of king salmon based on a decrease is correct, then king salmon costs about \$1.50 per pound to produce. If this is true, then even king salmon fails to produce net benefits.

Recommendations

Our results do not paint a very encouraging picture for the hatchery program. Based on our point estimates, the best alternative is to close the pink salmon hatcheries, or at least scale them back considerably. However, we would not recommend that the state force all hatcheries to shut down. Instead, we recommend that *if a region wants to continue with a hatchery program, that it should be funded by the local user groups rather than by the state.*

If the fishermen themselves fund the hatchery program, they will only choose projects which are cost-effective within their own region. There may still be regional effects in that production in one region causes prices to decline elsewhere, but whatever hatchery production remains will be cost effective. Table One compares the thirty year returns (undiscounted) for each alternative by region. Because we believe that our estimates of net benefits for Alternatives 2, 3, 4a, and 4b must be viewed with a great deal of caution, we separate them out in Table One.

We have bolded the number in each column that corresponds to the best alternative for the region under the assumption that the region is financing its own hatchery program. In the subset of alternatives excluding Alternatives 2, 3, 4a, and 4b, Alternative 5—shutting down the entire pink salmon hatchery production—is the best alternative for Kodiak, Prince William Sound, and Southeast. That is, if these regions could get the rest of the state to agree to follow alternative 5, they would get the highest returns under a self-financed hatchery program.

The question is would the other two regions also want to follow alternative 5? While Western Alaska would benefit if the pink salmon program be shut down, their first preference would be that the red salmon hatchery production be shut down (Alternative 6). However, since Western Alaska only has one hatchery, and it produces only chum, it cannot independently influence the behavior of the other regions. Cook Inlet is the odd one of the regions. Under a self-financing program, our estimates indicate that Cook Inlet would prefer everyone else shut down their king salmon programs. But since no other region will prefer this option, this alternative is not feasible. If every other region scales back pink salmon hatchery production, Cook Inlet is made worse off relative to the current production levels. Could Cook Inlet by itself influence the actions of the other regions? The answer is probably, though not definitely, "no." Prince William Sound is currently producing currently 124 m. pounds of pink salmon. Cook Inlet is currently producing under 7 m. pounds, of which less than half comes from hatchery production. Thus, even if Cook Inlet felt that it could produce pink salmon at a net benefit to its

fishermen, it is doubtful that it would have enough of an impact on prices to warrant the other regions changing their minds about scaling back their own pink salmon programs.

When Alternatives 2, 3, 4a and 4b are included, Kodiak, Southeast, Prince William Sound and Western Alaska all prefer shutting down either all pink salmon or the entire program. This suggests that if the hatcheries are self-financed, they will choose to scale back their operations on their own. Thus, we view turning over the financing of the hatcheries entirely to the regions as the best alternative for the state. The actions we predict the regions to take assumes that our point estimates are correct. If they are not correct, self-financing is still a better idea than continued state funding because it makes the regions themselves decide what levels of hatchery production give them the highest returns.

Conclusions

If our recommendations are followed, hatchery production of fish for sport and subsistence purposes will most likely not continue without some state funding. We have made no effort to analyze the net benefits from hatchery production on other user groups. The way that we have calculated hatchery costs suggests that the per pound costs obtained in our study are a reasonable approximation to the hatchery costs for fish (in the range of small changes in hatchery production) no matter what their use. To estimate more fully the benefits and costs to other user groups, the state would have to determine the net benefits to those groups.

There also may be strategic reasons for maintaining some hatchery production. For example, it appears that hatchery exports of pink salmon may be starting in the former Soviet Union. Chile also appears to have room for expansion of its farmed salmon program. If these countries are able to produce fish less expensively than Alaska, then there will be no way to stop them from entering in the long run. However, by maintaining some hatchery production, prices may remain depressed enough to prevent expansion in those areas. As long as the price is not driven down to the level that it would reach if those areas do enter the market, the hatchery dollars spent on prevention of entry may be well spent. However, this is not a strategy which can remain viable over the long run.

There are a number of other things that the state might do with money saved from the hatchery program. One obvious area is to engage in demand-enhancing activities, such as increased attention to quality and seeking out new product forms. Again, we emphasize that if such activities are truly profitable, then the fishing industry itself should be willing to finance them rather than the state.

Another area that appears to be fruitful for future exploration is the allocation among gear groups. In the cost study we observed that the different gear groups have vastly different levels of producer's surplus. The gear group that does the best is the set net fleets. This is mainly because these fleets have such low capital costs. The bottom line is it is more efficient to let the fish come to the fisherman than to have the fisherman go to the fish.

Finally, let us emphasize that our estimates of net benefit are based on parameters estimated from relatively short time periods and were extrapolated well beyond the time horizon for which accurate estimates may be obtained. There are also a number of exogenous factors, such as what is happening in the rest of the salmon suppliers' markets, that have changed far too rapidly over the last decade to allow precise estimates of where the industry will be in one, two or three decades. In spite of this, given our predictions of trends in the rest of the markets, we believe that the hatchery program, and especially the pink salmon program, should be scaled back. Our estimates suggest that to do so could result in an increase of net benefits to the state on the order of almost a half billion dollars over thirty years relative to current and planned production levels.

Table One: Net Benefits by Region, By Alternative

(Net benefits over thirty years in millions of 1992 dollars)

ALTERNATIVE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WM SD	SOUTH EAST	STATE TOTAL
(1) <i>Maintain current hatchery production</i>	1700.36	441.79	499.07	158.36	1201.76	4001.34
(5) <i>Eliminate pink salmon production</i>	1743.25	413.84	531.77	206.90	1565.88	4461.65
(6) <i>Eliminate red salmon production</i>	1779.38	413.77	422.60	201.97	1205.00	4022.72
(7a) <i>Increase pink salmon production by 15%</i>	1694.53	443.16	485.68	152.87	1155.14	3931.39
(7b) <i>Decrease pink salmon production by 15%</i>	1706.17	439.39	506.20	182.35	1256.94	4091.06
(8a) <i>Increase red salmon production by 15%</i>	1689.64	441.46	506.79	157.25	1191.55	3986.68
(8b) <i>Decrease red salmon production by 15%</i>	1711.29	437.49	488.84	166.35	1202.19	4006.16
(9a) <i>Increase chum salmon production by 15%</i>	1698.72	441.04	494.97	153.98	1211.24	4001.95
(9b) <i>Decrease chum salmon production by 15%</i>	1702.31	442.96	498.74	158.16	1193.73	3995.90
(10a) <i>Increase coho salmon production by 15%</i>	1698.45	440.36	498.31	157.17	1204.94	3999.22
(10b) <i>Decrease coho salmon production by 15%</i>	1701.52	444.58	499.33	157.63	1195.93	3999.00
(11a) <i>Increase king salmon production by 15%</i>	1699.54	443.07	498.68	157.80	1210.27	4009.37
(11b) <i>Decrease king salmon production by 15%</i>	1701.42	448.25	506.80	158.31	1196.23	4011.01
(2) <i>Planned hatchery salmon production levels</i>	1624.56	481.57	471.51	228.96	1151.24	3957.84
(3) <i>Eliminate entire salmon hatchery program</i>	1918.84	467.50	533.37	229.91	1471.58	4621.20
(4a) <i>Increase entire hatchery production by 15%</i>	1671.50	436.81	479.91	134.11	1122.38	3844.72
(4b) <i>Decrease entire hatchery production by 15%</i>	1724.08	445.81	499.93	217.09	1226.90	4113.80

Table Two: Hatchery Cost and Producer's Surplus per Pound by species

Alternative	Hatchery Cost (\$/lb)	Net Benefits (\$/lb)
(7a) Increase pink salmon production by 15%	0.056	0.066
(7b) Decrease pink salmon production by 15%	0.108	0.053
(8a) Increase red salmon production by 15%	0.346	0.142
(8b) Decrease red salmon production by 15%	0.221	0.154
(9a) Increase chum salmon production by 15%	0.093	0.095
(9b) Decrease chum salmon production by 15%	0.085	0.104
(10a) Increase coho salmon production by 15%	0.407	0.323
(10b) Decrease coho salmon production by 15%	0.272	0.360
(11a) Increase king salmon production by 15%	0.297	0.857
(11b) Decrease king salmon production by 15%	1.500	0.828

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From John Boyce

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FACSIMILE TRANSMITTAL SHEET

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TRANSMITTED TO: GRIMY FAY

DATE: 11/4/92

TIME: 11:00 am

PAGES: 25 to follow

MESSAGES: THIS IS THE TECHNICAL Report.

I trust the Appendices came through ok?

Will send the Exec Summary ASAP.

THANK YOU!!

*Are benefits to
State calculated to
include spin-offs
(employment, raw fish
tax, etc.) of heavy
big here? fishing industry*

A BENEFIT-COST ANALYSIS OF THE ALASKA SALMON HATCHERY PROGRAM

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A Report to the Legislature of The State of Alaska

November, 1992

**DRAFT: NOT FOR QUOTATION WITHOUT WRITTEN
PERMISSION FROM THE AUTHORS**

A BENEFIT-COST ANALYSIS OF THE ALASKA SALMON HATCHERY PROGRAM

Introduction

The hatchery program in Alaska was created in the early 1970's. At that time, Pacific salmon dominated the world salmon markets. Since then, there has been a rapid rise in the supply of salmon world-wide. In Alaska, this has been in large part due to production from the hatchery program. However, the increase in production has been worldwide, and it appears that supplies of salmon on the world market are more likely to continue to increase than to decrease. Given this backdrop, the Legislature of the State of Alaska asked for a cost-benefit analysis of the state-funded hatchery program. This report summarizes the findings of that study.

Since the hatchery program is funded by the State of Alaska, we considered only the interests of the state in our analysis. This means, for example, that benefits to consumers either in the U.S. or in other world markets were ignored completely. This is not to imply that these benefits do not exist but is recognition of the fact that they are not benefits that are captured by the State of Alaska. The benefits to the state were measured by two variables. First, we were interested in what the net benefits to the fishermen were from the hatchery program. That is, we wanted to estimate the return to fishermen above their costs that occurs under different hatchery production output levels. Second, we wanted to estimate the cost of producing benefits to the fishermen, which is the cost of running the hatchery program.

The hatcheries were surveyed to find out what they expected their costs to be if hatchery production for a particular species were increased or decreased. While there is some difficulty in interpreting these numbers in certain instances, measurement of the costs of the hatchery program are relatively straightforward.

The benefits to fishermen are not as easily determined. We considered fishermen's *producer's surplus* to be the appropriate measure of benefits to the fishermen. Producer's surplus measures the return above opportunity costs to the fishermen. If the fisherman does not expect to earn revenues higher than his or her next best alternative (their "opportunity cost"), then they choose not to fish. Any returns they get above the minimum required to attract them into the fishery are what we measure as the surplus. The surplus benefits may differ across fishermen because some fishermen may be willing to fish even when revenues are low, and others may not.

The *net benefits* to the state of the hatchery program are the net benefits to the fishermen as measured by producer's surplus minus the hatchery costs. This measure indicates the net benefits to fishermen above the costs of providing these benefits.

The calculation of the producer's surplus to the fishery is by no means a straight forward procedure. The request for proposals required that we consider a number of *alternative management plans* for the hatchery program. These management alternatives are described below in Table One. Each management plan was to be considered over a 15- and a 30-year planning horizon. To imagine that we can precisely predict events 15 or 30 years in advance based on a decade of data from an industry in transition is, of course, precarious at best.¹ However, given the world-wide trends in demand and supply as suggested by the events over the past several decades, we do have a rough idea of the direction in which the fishery is heading. Our estimates are likely to be very inaccurate within particular years, but should, on average, capture the trend. Since we are asked to conduct a cost-benefit analysis of the hatchery program over a long lifetime, the trend will be much more important than specific yearly predictions.

The model used to generate our projections for these 15- and 30-year planning horizons use results from three other parts of this study. For each management alternative, projections about the biological stocks were generated (Collie, 1992). These biological projections were then put into an international salmon demand model to make projections about the prices for each species in each area (Herrmann and Greenberg, 1992). The quantity and price projections were then used to estimate the costs to fishermen of participating in the fishery (Boyce, 1992). Each of these models are described in the citations.

Research objectives

The request for proposals outlined seventeen alternatives to consider. These are given in Table One.

Our complete reported findings are contained in Appendix One, Two, Three and Four. We report fifteen year projections for catch, revenues, producer's surplus, hatchery costs, and net benefits. For each management alternative, we report projections for Western Alaska and AYK combined (the part of the state with no hatchery program), and for Cook Inlet, Kodiak, Prince William Sound, Southeast, and for the state total. Thus, in each Appendix there are six tables on three pages for each alternative. At the bottom of each table we report the fifteen year sum, the thirty year sum, and the present value of the thirty year sum discounted at 4% real rate of interest.² The difference between the Appendices is that Appendix One reports the estimate of returns using our

¹While data for annual prices and quantities exist for several decades, inventory and export data restrict us to the years 1980 and beyond.

²We examined the cases of four and seven percent real rates of interest (i.e., we removed the inflation part of the interest rate since all dollars are expressed in real 1992 dollars). The seven percent discount rate figures are not contained in Appendix One, but do appear Appendix Four.

midpoint price estimates from the demand model. Appendix Two reports the estimates of returns under optimistic price projections, and Appendix Three reports the estimates of returns under pessimistic price projections. The data reported in the Appendices is aggregated to the regional level. In the actual simulations, *fleet* specific estimates of returns and costs were calculated. However, this data is too voluminous to be included in the report. Appendix Four contains summary data for present value calculations at 0, 4 and 7% discount rates.

Table One: The Alternatives Considered in the Policy Analysis

Case 1	Maintain current hatchery production
Case 2	Planned hatchery production levels
Case 3	Eliminate entire hatchery program
Case 4a	Increase entire hatchery production level by 15%
Case 4b	Decrease entire hatchery production level by 15%
Case 5	Eliminate entire pink salmon hatchery production
Case 6	Eliminate entire red salmon hatchery production
Case 7a	Increase pink salmon hatchery production level by 15%
Case 7b	Decrease pink salmon hatchery production level by 15%
Case 8a	Increase red salmon hatchery production level by 15%
Case 8b	Decrease red salmon hatchery production level by 15%
Case 9a	Increase chin salmon hatchery production level by 15%
Case 9b	Decrease chin salmon hatchery production level by 15%
Case 10a	Increase silver salmon hatchery production level by 15%
Case 10b	Decrease silver salmon hatchery production level by 15%
Case 11a	Increase king salmon hatchery production level by 15%
Case 11b	Decrease king salmon hatchery production level by 15%

The revenue data in each table represents the projected gross returns to the region or to the state from the salmon fishery. We estimated the costs to the fishermen as the minimum level of returns required before the fishermen would participate. Thus part of the revenues was the cost of hiring the resources away from their next best alternative. Since they would have earned returns equal to the value of their next best alternative, these costs are real economic costs.³ The *producer's surplus* is the difference between the estimated revenues and costs. The producer's surplus measures the net benefits to the

³It is inappropriate to simply view the cost part of the revenues as benefits because they represent expenditures to the other sectors of the state. While it is true that they represent expenditures to other sectors, they also represent what was foregone by the fishermen if they had been engaged in their next best alternative.

fishing sector. Again, the cost of providing these net benefits to the fishermen is the cost of the hatchery program. To get the net benefits to the entire hatchery program, we subtracted the hatchery costs from the producer's surplus.

Caveats and Assumptions

Before we explore the actual findings, let us explain why we believe our estimates must be treated with some caution. First, these predictions are based on models using data from only a small number of years. The demand data uses quarterly data from 1982 to 1991. The cost data was generated entirely from data for 1990. To extrapolate 15 or 30 years based on such a short time series is very dangerous. Certainly projections made in the 1960's could not have foreseen the changes that occurred one or two decades later.

The analysis we conducted concentrates only on the commercial fisheries. We separated out the hatchery return and costs that went to other uses (i.e., sport and subsistence) from the analysis. This means that the benefits of production of kings, silvers, and reds that goes to sport fish purposes (especially in Southeast) and the species, especially chum, that goes to subsistence purposes are ignored by our analysis. We have also ignored the hatchery costs associated with these uses. There may be some problems with the way we did that. We assumed that if 75% of the fish were returned for commercial catch (including the commercial share of the cost recovery catch), then 75% of the hatchery costs could be attributed to the commercial catch. This may be untrue in the sense that the costs of production of sport and subsistence fish may in part be reduced by the costs incurred producing commercial catch.

All of our analysis is based on point estimates. Even though we predict high and low prices, we are still comparing revenue cases against the base cases for average vs. average prices, high vs. high prices, and low vs. low prices. In addition, our predictions of total revenues and producer's surplus are missing confidence levels which could make some of our findings insignificant.

In addition, the production levels under each of the elimination alternatives are vastly different from the production levels we observed in the historical time period used to estimate our demand and fishing cost models. All of our estimation of demand and fishing cost parameters occurred with hatchery and production figures that were considerably higher than the levels considered in Cases 3, 5 and 6. It is less true for Case 6 because hatchery production of red salmon is small relative to the total quantity of wild stocks of red salmon. This is particularly true for Cases 3 and 5, which involve drastic reductions in the pink salmon catches. Because of this, we are forced to extrapolate well beyond the data in our analysis. The result of the extreme extrapolation may be to predict prices which are above their historical levels.⁴

⁴This occurs with some extent to our predictions of pink salmon prices. If the pink salmon program is eliminated, we estimate pink prices to average about \$0.46 per pound ex vessel. Over the period 1980 to 1991, nominal prices averaged only \$0.31 per pound, although in approximately one-third of the years

Also, it was necessary to aggregate Pacific salmon into high-valued (sockeye, king, and coho) and low-valued salmon (chum and pink) in the demand side of the model. This was due to the need to simplify the number of specified species in order to estimate the model. However, because of this, there are no *empirical estimates* of cross-price effects between species within an aggregate grouping. As a result, ad hoc assignments to substitution effects between species within each aggregate grouping were made. For example, we assumed that the strength of the substitution effect between pink and chum salmon to be one-quarter of the strength imposed in the model, and vice versa. The assumed cross-price effects were kept fairly low in order to err on the side of conservatism.⁵ Similar assumptions were made for other species. We do have empirical cross-price effects for species within the low-valued grouping on species within the high-valued grouping, and vice versa. These are reported and discussed in the demand model report (Hermann and Greenberg, 1992).

It was not possible to use the ad hoc cross-price effects between species within a particular grouping when there was simultaneous changes to salmon species within the aggregate groupings because the movements of own-price effect and cross-price effect could not be sorted out. Because of this, an accurate estimation of cases 2-4, where there were simultaneous changes in hatchery production, was not possible. Because the model-imposed cross-price effect within the groupings are overstated, the revenues assigned to cases 2, 3, and 4a will be understated. For this reason, only the cases of 1 and 5-11, when the ad hoc cross-price effects within the aggregate salmon groupings can be imposed, offer realistic revenue forecasts. The losses found in cases 2-4 must be seen as absolutely worst case scenario and probably should not be taken seriously.

The fishing cost data was calculated as follows. In the fishing cost model, we estimated a model predicting the number of fishermen participating in a particular opening based on the total run strength as measured by the total revenues earned in the opening. We found a very consistent relationship that as total revenues rise, the number of fishermen also increased. The relationship also indicated that to add another fisherman, the revenues would have to rise by a larger amount than was required to attract the previous fisherman. This suggested that fishermen have different costs of fishing and that those with the lowest costs entered first. The cost equation was then derived from the participation equation by solving for the average revenue given the number of fishermen predicted to participate. The behavioral assumption was that the last fisherman to enter expected to earn just enough in revenues to cover his costs of fishing. Thus the average revenues for each opening gave us a measure of the fishing cost of the last fisherman participating in the opening. Since we observed a large number

the real 1992 dollars prices rose to this level. The two most recent cases, 1987 and 1988, are years for which pink salmon volumes were at their lowest over the period.

⁵We examined the results using the full cross-price effects. The result was that a decrease in pink salmon caused chum salmon revenues to increase dramatically. This made the effect of reducing the pink salmon program even less costly since there was a large compensation due to an increase in chum revenues. It appears that the relationship between chum and pink salmon revenues is an issue which deserves more research.

of openings with different numbers of fishermen, we obtained an estimate of fishing costs as a function of the number of participants.

In the extrapolation of the fishing cost model to future years, we took the 1990 run for the fishery as our guide for how the run would be dispersed over time and across the statistical areas within the fishery. If the future year showed an increase over the 1990 data for a particular species of, say, 10%, then we inflated the catch of that species by 10% for each opening over the season. Having done this for each species, we then multiplied the estimated catch by the price per pound for each species. We then used the data on percentage by species of the catch and of total revenues per opening to make a prediction of the number of fishermen participating in each opening throughout the season using the parameters of our participation model estimated on 1990 data. To obtain our estimate of fishing costs for the opening, we utilized the relationship between average revenues and the number of fishermen and the behavioral assumption that the last fisherman to enter earned revenues equal to their fishing costs. The fishing costs for the entire opening were obtained by summing the fishing costs for each fisherman up to the estimated number of participants. The fishing costs for the season were simply the sum of these fishing costs over all of the openings. Producer's surplus was estimated as the difference between the fishing cost estimates and the revenue estimates.

One problem with our extrapolation is that we did not have estimates of which statistical areas would be affected by the changes in the hatchery stocks production. Thus we used the average cost over all statistical areas weighted by the distribution of 1990 catch over those areas. Thus if the distribution of catch changes or if the 1990 catch was aberrant in the distribution of returns, we would introduce error.

A more serious problem which is consistent across all of the analyses of alternatives is the problem of extrapolating cost data from one fishery to another. In particular, the estimates of fishing costs was conducted for only a select number of fisheries. For all other fisheries, we used the *average* estimate of fishing costs for similar gear type fleets elsewhere in the state. In particular, this problem is acute for Western Alaska. The main problem here occurs in the drift net fleet. The Bristol Bay drift net fleet is about 2,000 vessels strong. None of the other drift net fleets are anywhere near this size. Thus our estimates of producer's surplus in Western Alaska may be off by an order of magnitude. While it is true that the relative error should be constant across the alternatives, the magnitude of that error may be considerable. We doubt, however, that it accounts for the results of our analysis with regard to the elimination of all, or portions, of the hatchery program.

A technical caveat on the interpretation of producer's surplus should also be mentioned. Producer's surplus in essence measures the "skill rents" to fishermen. That is, given the common property ownership in the fishery, the reason economic rents even exist at all is because of differences in the fishermen. These differences are measured as the minimum amount of revenues per fishermen that are required before a particular fisherman decides that it is profitable to participate in an opening. If these rents are transferable, then the present value of the producer's surplus should equal the value of the permits in a particular fishery. However, if the skills are not transferable, then the

correlation between the producer's surplus and the value of the permits will be dampened. (The correlation should be positive under any conditions.) If the economic skill rents are not transferable, then the present value estimates of producer's surplus should be in excess of the value of the permits.

Finally, our estimates of catch, revenues, and producer's surplus for the second 15 years of the planning horizon are based on the average of years 10 to 15 (2001-2006). The cost estimates from the hatcheries were provided by the hatcheries for those years.⁶

Returns to the state if hatchery production continues at current levels

Under current hatchery production levels (Case 1) we estimated the net benefit to the state to be on the order of \$109.71 m. ($m = 10^6$) in 1992. The net benefits were projected to rise steadily in real (1992) dollars over the thirty year planning horizon. By 2006 we projected the net benefits to the state to be \$154.37 m. per year. The thirty year average was estimated to be \$140 m. Over thirty years, we estimated that the salmon fishery with the hatchery program at its current levels would bring in \$4.001 b. ($b = 10^9$) in net benefits (\$2.329 b. in present value at 4% discount rate) to the Alaskan Economy on revenues of \$16.075 b. The difference over the thirty year planning horizon between the gross revenues and the net benefits was made up of hatchery costs (\$859 m.) and fishery costs (\$11.215 b.). This data is based on the midpoint price estimates from the demand model (Appendix One). The optimistic price estimates (Appendix Two) yielded an undiscounted return of \$4.731 b. and the pessimistic price estimates yielded an undiscounted return of \$3.548 b. over the 30 years. In present value of 1992 dollars discounted at four percent, the estimates for current production levels are \$2.330 b. for the midpoint, \$2.746 b. for the optimistic, and \$2.071 b. for the pessimistic price predictions. Thus our estimates vary by about 1.2 b. undiscounted dollars to about 700 million discounted dollars over the thirty year planning horizon. This magnitude of prediction error is present in all our analysis.

The distribution of the undiscounted \$4.001 b. net benefits over the next thirty years under current hatchery production levels was as follows. The largest share is in Western Alaska (dominated by Bristol Bay), with about \$56.67 m. in net benefits per year over the next thirty years, for a total of \$1.700 b. (present value of \$933.40 m. at 4% discount rate). The next largest share went to Southeast, with \$40.03 m. per year for a total of \$1.201 b. over the thirty year lifetime (present value of \$689.34 m.). Kodiak had net benefits of \$16.64 m. per year for a thirty year total of \$499.07 m. (PV of \$288.69 m.) Cook Inlet had net benefits projected to be \$14.73 m. per year for a thirty year total of \$441.79 m. (PV of \$271.08 m.). Prince William Sound had net benefits projected to be \$5.279 m. per year for a thirty year total of \$158.36 m., or a present value of \$87.41 m.

⁶We were requested to use the 15th year to predict the final 15 years in the RSA. However, we found that our demand model predictions for the fifteenth year were quite a bit higher than previous years, so we used the 5 year average instead. The relative effect is that all revenues are slightly lower than would have occurred if we had used the 15th year. However, none of the relative rankings of the alternatives is affected by this change.

We shall speak more to the issue of the distribution and the reasons for the distribution below.

Comparing planned hatchery production with current hatchery production

The second alternative considered was the "planned hatchery production levels," Case 2. This comparison is made in Table Two. The catch levels projected by the hatcheries were obtained in a survey conducted by the Department of Fish and Game, FRED division. We estimated that if the state follows the planned hatchery production alternative the thirty year undiscounted sum is \$3.958 b. (\$2.303 b. if discounted at 4%), for an average net benefit of \$132 m. per year. The estimated returns under the current hatchery production levels were \$133 m. per year, or about a million dollars a year higher. Our estimation results of Case 2 should be viewed as a lower bound prediction of net benefits for Case 2. The reason is that the simultaneous large increases in a number of species under the planned output levels forces into play a number of complex cross price effects, which our demand model is not well adapted to consider.

The distribution of net benefits under the planned hatchery production levels also changes from the current levels. Under the planned levels, Prince William Sound will gain almost seventy million dollars over thirty years, up to net benefits of \$228.96 m. from net benefits of \$158.36 m. under current levels.⁷ Cook Inlet also gains, increasing to \$481.57 m. from \$441.79 m. under current levels. However, these projected gains are more than offset by the projected losses elsewhere. Western Alaska loses the most, down to \$1624.56 m. from \$1700.36 m. over thirty years. Southeast is projected to have net benefits under the planned case of \$1151.24 m., down from \$1201.76 m. under the current levels. Kodiak also loses under the planned alternative relative to the current levels since net benefits drop to \$471.51 m. from \$499.07 m. The regions that gain, Prince William Sound and Cook Inlet, gain by an amount less than the remaining regions lose by average of \$1.45 m. per year. Thus our projection suggests that the current hatchery levels are to be preferred over the planned hatchery production levels.

It is instructive to look at what is changing under the planned hatchery levels relative to the current hatchery production levels. The thirty year sum (undiscounted) totals for each alternative are given below in Table Two.

The catch differences between the current (Case 1) and the planned (Case 2) production are that Cook Inlet, Prince William Sound, and Southeast all have larger catches under the planned than under the current case. Prince William Sound accounted for the largest share of the increase, adding 487 million pounds over the thirty year period. Cook Inlet and Southeast increase catch by about 138 and 115 million pounds, respectively. The catch in Kodiak and Western Alaska are almost unchanged. In net,

⁷The figures we are citing are the undiscounted sums. The appropriate measure for cost-benefit analysis is the discounted figures. We found that the discounting did not affect the relative standings of the various alternatives since costs and benefits are dispersed fairly evenly over the planning horizon. Since the undiscounted numbers are the least confusing to look at, we use them in the analysis.

there is an increase of 739 million pounds of fish caught over the thirty years, or about 24.6 million pounds per year more in catch.

Table Two: Regional summaries for current (Case 1) and planned (Case 2) hatchery production

(millions of pounds and millions of 1992 dollars)

Case 1: Current Level

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.77	7078.92	1700.36	0.00	1700.36
Cook Inlet	1702.43	1572.88	508.05	66.26	441.79
Kodiak	2425.80	1466.39	548.09	49.02	499.07
Prince Wm.	5215.02	2422.53	536.05	377.69	158.36
Southeast	6153.45	3534.28	1568.25	366.48	1201.76
State Total	23332.47	16075.00	4860.79	859.45	4001.34

Case 2: Planned Level

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.79	6891.17	1624.56	0.00	1624.56
Cook Inlet	1840.07	1698.54	549.97	68.40	481.57
Kodiak	2424.90	1420.60	520.53	49.02	471.51
Prince Wm.	5702.03	2592.98	616.54	387.58	228.96
Southeast	6268.58	3506.87	1537.80	386.56	1151.24
State Total	24071.37	16110.16	4849.40	891.55	3957.84

Consider how the changes in the catch affected the changes in revenues. In net, revenues increased to \$16.075 b. under the planned production levels from \$16.110 b. under current production levels. This increase of \$35.16 m. over thirty years is relatively small, about \$1.17 m. per year. The increase in revenues was not uniform across the regions, however. Revenues in Cook Inlet and Prince William Sound increase under the planned hatchery production relative to the current, but all other areas would have a decrease in revenues. Cook Inlet revenues increase by \$125.66 m., or about \$4.19 m. per year. Prince William Sound revenues increased by \$170.45 m., or an average of \$5.68 m. per year. Western Alaska, Kodiak, and Southeast all had reductions in revenues. Western Alaska revenues decreased by \$187.75 m., or an average loss in revenues of \$6.26 m., per year. Kodiak revenues decreased by \$45.79 m., or by \$1.58 m. per year. Southeast lost an additional \$27.41 m., or about \$0.91 m. per year.

The revenue changes are discussed in more detail in the demand analysis report. However, the main effect on revenues of the increase in production in Prince William Sound, Cook Inlet, and Southeast is to depress revenues in three areas (Western Alaska, Kodiak, and Southeast), and increase revenues in two areas (Cook Inlet and Prince

William Sound). In net, the increases in revenues were greater than the losses. The curious finding here is that increases in Southeast, when coupled with the increases in Prince William Sound and Cook Inlet, actually lead to decreases in revenues in Southeast. It is doubtful that taken by itself, an increase in Southeast production would have depressed revenues in Southeast. However, when coupled with the increases in Prince William Sound and Cook Inlet, the net effect was a decrease in Southeast revenues.

The producer's surplus measures the net benefits (revenues minus costs) to the fishermen in each region. If the hatchery program continued at planned levels rather than at current production levels, we estimated that while gross revenues increased by \$35.16 m. over the thirty year period, net revenues to the fishermen measured by producer's surplus actually *decreased* \$11.39 m. As with the revenues, the distribution of gains and losses was not the same across regions. Cook Inlet and Prince William Sound each experienced gains in producer's surplus. Each of the other regions experienced losses in producer's surplus. The net gains and losses are as follows: Prince William Sound was the biggest gainer, with an increase in producer's surplus of \$80.49 m., or \$2.68 m. per year. Cook Inlet showed gains of \$41.92 m., or \$1.40 m. per year. The total gain of these two areas was \$122.41 m. total over thirty years, or \$4.08 m. per year. The biggest loser was Western Alaska. The losses there would be \$75.80 m. over thirty years, or \$2.53 m. per year. Southeast lost the next most, having a reduction in producer's surplus of \$30.45 m. over thirty years, or \$1.02 m. per year. Kodiak would lose producer's surplus of \$27.56 m. over thirty years, or \$0.92 m. per year. The totals for the three areas losing producer's surplus are losses of \$133.81 m. over thirty years, or \$4.46 m. per year. Compare this with the total gain per year in Cook Inlet and Prince William Sound, and there is a net loss of \$0.38 m. per year relative to the current case.

While the producer's surplus net gains and losses are almost a wash, with the losers losing about \$0.38 m. a year more than the winners are gaining, the true measure of the difference is in the hatchery costs. Given net losses to fishermen on the order of \$11.69 m. over thirty years, we estimate that hatchery costs will rise by \$32.10 m. dollars over the thirty year planning horizon. That is, in addition to the net losses in producer's surplus by fishermen of \$11.69 m., there is also an increase in hatchery costs of \$32.10 m. The total cost of the planned hatchery output relative to the current hatchery output levels is thus the sum of the reduction in producer's surplus plus the increase in hatchery costs. This sums to a net loss of \$43.79 m. over the thirty year planning horizon, or a net cost of \$1.46 m. per year. In present value terms at a discount rate of 4%, the difference is -\$26.62 m. That is, our estimates say that if we follow the planned levels rather than the current levels, it will be as though we lost \$26.62 m. today.

The direction of the changes is consistent under alternative assumptions about the prices. If prices follow the optimistic projections instead of the midpoints, the current production levels provide an estimated net return to the state over thirty years of \$50.93 m. undiscounted dollars and \$30.17 m. discounted dollars. Under the pessimistic price scenario, the difference is \$41.26 m. undiscounted or \$25.47 m. discounted dollars at a 4% rate of discount.

Comparison of eliminating entire portions of the hatchery program with maintaining current production levels

Our calculations suggest that two alternatives dominate all other alternatives in producing net economic benefits to the state. These alternatives are Case 3, elimination of the entire hatchery program, and Case 5, elimination of the entire pink salmon program. In addition, we find that the next best alternative is a reduction of the entire program by 15%. However, the order of magnitude difference between a reduction of 15% and eliminating all of the pink salmon program is over \$350 m. over thirty years (undiscounted) and the difference between a 15% reduction and eliminating the entire program is over \$500 m. over thirty years. These numbers suggest that large decreases in either the entire hatchery program or at least in pink salmon are warranted.

We believe that our numbers are as accurate as can be obtained under current data limitations. However, we warn that our estimates of returns to the state under the elimination alternatives must be viewed with some caution. In particular, our earlier warnings that these cases are forcing us to extrapolate beyond the data used to estimate parameters in our model is relevant for these cases. In addition, the cases in which the entire program is eliminated (Case 3) or reduced by 15% (Case 4b) involves complicated cross price effects which our demand modeling may be incapable of capturing. Thus, the results from these particular cases should be somewhat discounted.⁸ In spite of this, we believe that there is a serious message in our findings: it appears to us that the hatchery program, especially with respect to pink salmon, needs to be scaled back considerably, if not entirely.

Table Three contains summary statistics for the 30 year sums (undiscounted) for the current hatchery output levels (Case 1) as well as each of the three cases where some (Case 5, elimination of pinks, and Case 6, elimination of reds) or the entire program is eliminated (Case 3). Looking at the statewide total net benefits under each program, it is clear that elimination of all or some portion of the program results in the largest net benefits to the state. In particular, the thirty year sum of undiscounted net benefits under the current hatchery output levels is estimated to be \$4.001 b. Under Case 3, the eliminate the entire program alternative, we estimate net benefit to the state to be \$4.621 b. dollars, or an increase of \$620 million over the next thirty years, which is approximately a net increase in the wealth of the state by \$20.67 m. per year over the next thirty years. Under Case 5, elimination of the entire pink salmon portion of the hatchery program, we estimate that the state receives returns of \$4.461 b. dollars over the thirty year planning horizon. This is \$460 m. more than under the current hatchery output levels, or an increase in welfare of the state of \$15.33 m. per year. Elimination of

⁸This warning is relevant also for Case 2 and 4a. We emphasize the warning for Case 3 and 4b because it is for these cases that we find point estimates suggesting the largest gain in benefits to the state.

Table Three: Comparison of eliminating the entire hatchery program (Case 3), the entire pink salmon hatchery production (Case 5), and the entire red salmon hatchery production (Case 6)

(millions of pounds and millions of 1992 dollars)

Case 1: Current Level

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.77	7078.92	1700.36	0.00	1700.36
Cook Inlet	1702.43	1572.88	508.05	66.26	441.79
Kodiak	2425.80	1466.39	548.09	49.02	499.07
Prince Wm.	5215.02	2422.53	536.05	377.69	158.36
Southeast	6153.45	3534.28	1568.25	366.48	1201.76
State Total	23332.47	16075.00	4860.79	859.45	4001.34

Case 3: Eliminate all species in 1993

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.24	7983.52	1918.84	0.00	1918.84
Cook Inlet	1259.05	1488.38	469.45	1.94	467.50
Kodiak	1808.76	1437.79	534.75	1.38	533.37
Prince Wm.	1548.73	1190.36	237.71	7.80	229.91
Southeast	4350.53	3234.71	1482.64	11.06	1471.58
State Total	16802.32	15334.70	4643.38	22.18	4621.20

Case 5: Eliminate Pink Salmon in 1993

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.77	7252.70	1743.25	0.00	1743.25
Cook Inlet	1362.23	1506.21	480.10	66.26	413.84
Kodiak	2135.11	1543.94	580.79	49.02	531.77
Prince Wm.	2199.21	1644.75	328.74	121.85	206.90
Southeast	5920.16	3972.75	1788.10	222.22	1565.88
State Total	19452.47	15920.34	4920.99	459.34	4461.65

Case 6: Eliminate Red Salmon in 1993

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.77	7416.14	1779.38	0.00	1779.38
Cook Inlet	1604.31	1495.05	480.03	66.26	413.77
Kodiak	2266.73	1296.00	471.62	49.02	422.60
Prince Wm.	4988.08	2088.72	473.67	271.69	201.97
Southeast	6122.87	3538.60	1571.48	366.48	1205.00
State Total	22817.76	15834.51	4776.17	753.45	4022.72

the red salmon program (Case 6) is also projected to increase the net returns to the state, but elimination of the red salmon program has a much smaller effect than elimination of the pink salmon program. If the red salmon production is eliminated, the thirty year return to the state is estimated to be \$4,022 b. dollars. This is only \$21 m. more than under current production levels over thirty years, or about \$0.70 m. per year.

The differences in total net benefits to the state cannot be explained by catch and revenue data alone. What we find is that elimination of any portion of the program causes catch to decrease. This results in a reduction in revenues relative to the current production levels. Thus the gain in net benefits is not due to a gain in revenues but to a decrease in costs of running the hatchery program. Under the eliminate all alternative (Case 3), catch decreases by 28%, down to 16,802 b. pounds over 30 years from 23,332 b. pounds under the current output level. However, revenues only decrease by 4.6%, down to \$15,335 b. from \$16,075 b. over thirty years. Elimination of the pink salmon program also reduces total estimated catch, although not by as much as elimination of the entire hatchery program. The reduction in the catch due to the pink salmon hatchery program would be a drop to 19,452 b. pounds over thirty years from the 23,332 b. under current output levels, or a reduction by 16.6% in catch. Revenues (undiscounted) would drop to \$15,920 b. from revenues of \$16,075 b. under the current output levels, or a drop of only 1.0% over the thirty years. If the red salmon hatchery production is eliminated, total catch drops by a much smaller amount, down to 22,817 b. pounds over thirty years from the 23,332 under current output levels. This drop of 2.2% causes a reduction in revenues to \$15,834 b. dollars over thirty years from \$16,075 under current output levels. The percentage reduction in revenues is 1.5%. The reduction in revenues appears to occur because of cross-price effects on the lower valued species.

The net return to the fishermen measured by producer's surplus is a much better measure of the value of the hatchery program to fishermen. We find that relative to the current production level of Case 1, producer's surplus actually increases by 1.2% under Case 5, the elimination of the pink salmon hatchery program. The increase is relatively small, \$60.20 m. over thirty years, or \$2.01 m. per year. Producer's surplus is estimated to decrease if either the red salmon program is eliminated or if the entire hatchery program is eliminated. While the producer's surplus for the entire state increases if the pink salmon program is eliminated, not every region has gains under the elimination of the pink program. In particular, producer's surplus decreases in Prince William Sound and Cook Inlet under each of the elimination alternatives relative to current levels. Western Alaska gains producer's surplus in each elimination scenario relative to the current levels, and Southeast gains big if pinks are eliminated, slightly if reds are eliminated, and loses if all species are eliminated. Kodiak gains if pinks are eliminated, but loses if reds or all species are eliminated.

It is only in the elimination of pink salmon that the net change in producer's surplus summed over all of the regions is positive. That is, in the elimination of pink salmon alternative, we estimate that the gains in producer's surplus to regions gaining are more than sufficient to compensate the losses in Prince William Sound and Cook Inlet. This is not true of either the elimination of the entire salmon hatchery program or the

elimination of the red salmon hatchery program alternatives. In each of those cases, the increase in producer's surplus benefits to the gaining regions is less than the loss in producer's surplus to the losing regions. Under elimination of the entire hatchery program, we find that undiscounted producer's surplus to fishermen over thirty years decreases to \$4.643 b. from \$4.860 b. under the current hatchery output alternative, for a decrease of \$217.41 m., or a decrease of about \$7.25 m. per year. Under the elimination of reds alternative, we find that fishermen's producer's surplus decreases to \$4.776 b. from the \$4.860 b. under the current hatchery output levels; or a decrease of \$84.62 m. over thirty years, or \$2.82 m. per year.

From a state-wide perspective, the changes in producer's surplus is only one part of the equation. The other part is the hatchery costs. Under the current production levels, to produce \$4.860 b. in producer's surplus over the next thirty years, the state spends \$859 m., for a net benefit of \$4.001 b. In fact, we find that when changes in the hatchery costs are taken into account in addition to the changes in the producer's surplus, each elimination alternative dominates the current output level alternative. Furthermore, the net effect by region shows that each region also gains with the exception of Cook Inlet in the cases where either pink or red salmon are eliminated, and for Kodiak in the case where red salmon is eliminated. The biggest surprise in this result is our finding that when hatchery costs are included, Prince William Sound also gains in net by eliminating each of the programs. Thus if the financing for the hatchery program were to entirely be financed within the region, the best alternative to Prince William Sound would be to eliminate the hatchery program given that the same is occurring throughout the rest of the state.

Under the elimination of the entire hatchery program, the producer's surplus decreases by \$217.41 m. over thirty years, but this is more than offset by a decrease in hatchery costs of \$837.27 m. Thus the net gain to the state of \$619.86 m. over thirty years is due to savings in the cost of the hatchery program. In essence, this tells us that the cost to provide fishermen with \$217.41 m. in additional producer's surplus is an additional \$837.27 m. in hatchery costs. This means that if the state wishes to increase the producer's surplus of fishermen by \$217.41 m., by giving a direct subsidy to the fishermen of the \$217.41 m. in lost producer's surplus instead of running the hatchery program, the state would save \$619.86 m. over the next thirty years.

Under the elimination of the pink salmon program, there are two sources of gain. First, producer's surplus actually increases by \$60.20 m. Secondly, the cost of the hatchery program declines by \$400.11 m. over the thirty year planning horizon. This says that by saving itself \$400.11 m. in hatchery costs, the state could actually increase fishermen's producer's surplus by \$60.20 m. over the next thirty years. Of course, not all regions gain by the increase in producer's surplus, but the losses to the regions that do lose is \$60.20 m. less than the gains to regions that gain.

Under elimination of the red salmon program, the fishermen suffer net losses in producer's surplus of \$84.62 m. However, this is more than offset by the \$106 m. in savings from running the red salmon hatchery program. The net effect of eliminating the

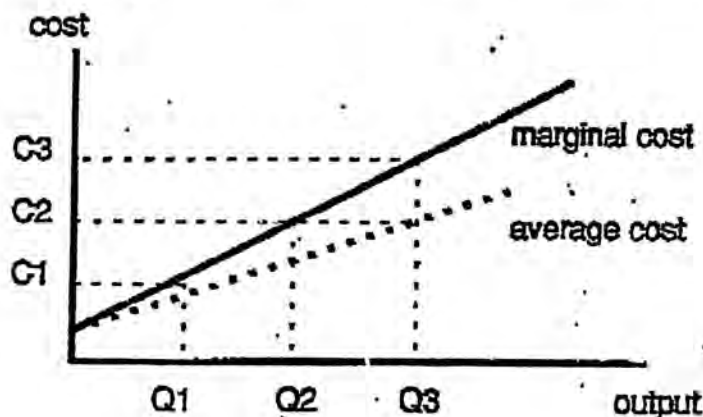
red salmon program is an increase in net benefits to the state of \$21.34 m., or about \$0.71 m. per year.

The cost per fish of the hatchery program

Our analysis of the potential effects of elimination of the hatchery program, or of some of its parts, reveals some interesting information about the cost per pound of fish of the hatchery program. Eliminating the pink salmon program shows that the estimated catch over thirty years will drop by 3,880 b. pounds. The reduction in hatchery costs due to eliminating the pink salmon hatchery program causes hatchery costs to decline by \$400.11 m. Thus the cost per pound of the pink hatchery program is roughly 10.3 cents per pound. This is less than 2 cents per pound below the price being offered in 1991 when pink salmon were left to rot. Given that fishermen could not afford to fish at 12.1 cents per pound, it suggests that pink salmon prices have to be over 22.4 ($= 10.3 + 12.1$) cents a pound before producing hatchery fish is profitable.

A similar comparison can be made for the red salmon program. The reduction in catch due to eliminating the red salmon program is 514.71 m. pounds over thirty years. The estimated savings in costs due to the elimination of the red salmon program are \$106.00 m. undiscounted dollars over thirty years. Thus the estimated cost of producing a hatchery raised red salmon is 20.6 cents per pound on average.

Figure One: Marginal and average hatchery costs



Two points should be made about the foregoing analysis. First, the cost of producing a pound of red salmon by the hatchery program appears to be almost twice as much as the cost of producing a pink salmon. This explains why it is that the elimination of the some red salmon hatchery production may possibly be a good idea. A second point has

to do with the way in which we have measured the change in hatchery costs. The survey filled out by hatchery producers asked the question of what would be the change in their operating costs if either the red or pink salmon programs were eliminated.

There is good reason to believe that the answers given by the hatcheries will tend to understate the cost of an additional hatchery produced fish. Consider Figure One. In Figure One, there are three different levels of output depicted. The marginal cost line measures the cost of an additional unit of output. For example, the cost of the output Q1 is C1. If output were to be increased to Q2, then the cost of the cost of the Q2th unit would be C2. The average cost if Q2 is produced would be the mean of C1 and C2. Since the average cost includes units of output that have lower marginal costs, the average cost is less than the marginal cost.

To further examine the hatchery cost per pound of various species, we collected data from each of the cases 7a, 7b through 11a, 11b, which considers increases or decreases for the particular species by 15% over current commercial catch. The data in Table Four shows a couple of things. First, the relationship between the cost per pound of an increase and a decrease in hatchery output of each species is consistent with what we would believe to be true of costs for red, chum and coho salmon. However, it does not appear to be true for king and pink salmon. For pink salmon, we have that the marginal cost (on average) of an increase by 15% is 5.6 cents per pound. However, the average cost of pink salmon already produced is 10.8 cents per pound. This is inconsistent with what we have shown to be expected in Figure One. The costs are estimated from the hatchery responses to the question of the change in costs to a 15% increase or a 100% decrease. To get a measure of the cost of a 15% decrease, we took 15% of the reported costs of a 100% decrease. The king salmon data appears to suffer from the same problem. It is our feeling that the cost associated with the increase in 15% is the more reliable figure since it is directly estimated by the hatcheries themselves. However, the figure given for the decrease is obtained by imposing the restriction that the total commercial share of costs of all species produced add up to the total commercial costs. This restriction is not imposed by the increase in production data.⁹ Again, a problem only appears to occur with the pink and king salmon hatchery costs.

⁹The cost data provided by the hatcheries was not entirely reliable. We found that if we added up the total cost savings for the commercial portion of the hatchery output, we generally got a number that was somewhat less than the total cost of the current commercial portion of hatchery costs. We adjusted the figures so that the sum of the 100% reductions would add up to the current hatchery costs attributable to commercial catch (i.e., including the commercial share of the cost recovery catch). For example, the total costs reduction from eliminating all commercial hatchery programs in Prince William Sound accounted for only about 50% of the total current level of commercial hatchery costs there. Thus we increased their estimate by a factor of two to get all costs to be accounted for. This adjustment may account for our difference in estimates of cost for increases versus decreases.

Table Four: The hatchery cost per fish for a 15% change in returns by species

(millions of pounds and millions of 1992 dollars)

	CATCH	HATCHCOST	ACATCH	ACOST	\$/LB
Current Level	23332.47	859.45	****	****	****
Increase Pink	23904.53	891.71	572.06	32.26	0.056
Decrease Pink	22774.95	799.44	557.52	60.01	0.108
Increase Red	23404.47	884.36	72.00	24.91	0.346
Decrease Red	23260.40	843.55	72.07	15.90	0.221
Increase Chum	23615.89	885.79	283.42	26.34	0.093
Decrease Chum	23049.04	835.32	283.43	24.13	0.085
Increase Coho	23357.68	869.71	25.21	10.26	0.407
Decrease Coho	23305.74	852.18	26.73	7.27	0.272
Increase King	23346.81	863.71	14.34	4.26	0.297
Decrease King	23318.08	837.86	14.39	21.59	1.500

Since the difference in hatchery costs has the greatest effect on our cost-benefit calculations in the pink salmon case, we consider what would happen if we have overstated our estimate of cost savings from eliminating pink salmon production. We estimated our cost savings to be about 10 cents per pound. Suppose that instead they had been only 5 cents per pound, which is being charitable to the hypothesis that we are wrong. Then under Case 5, hatchery costs would have decreased by \$200 m. over thirty years instead of by \$400 m. as we have estimated. Elimination of the pink salmon hatchery production would still result in an increase over current hatchery levels of \$260 m. dollars over thirty years, undiscounted. Thus, even at 5 cents a pound hatchery production costs for pink salmon, the elimination of pink salmon alternative is considerably more attractive than any other alternative save the elimination of the entire program.

Comparison of current hatchery production levels with 15% increases and decreases in all hatchery produced stocks

The next set of alternatives we consider are the alternatives in which either all hatchery production is increased by 15% (Case 4a), or all hatchery production is decreased by 15% (Case 4b). Before we turn to the analysis of the actual alternatives, we want to remind the reader of the main caveat having to do with these alternatives. That is, because all hatchery production for all species are simultaneously increasing or decreasing by 15%, there are a number of complicated interaction effects that are taking place. Our demand models are very weak in this respect. Because we restricted the international level of the demand model to low and high valued species, we do not have

estimates of substitution elasticity's that were calculated within each group. To estimate prices by species we used correlation's between the species price and the aggregate price for the group. While these correlation's give us an idea about how the relative prices of the species move in relation to one another, they do not give us a measure of the substitution elasticity between species. Therefore, when all species are simultaneously increasing or decreasing, we end up with a measure of correlation's between price movements. The problem is that a salmon is not a salmon. Pink and chum salmon, for example are very different from one another, and there is no a priori reason to believe that the correlation between prices conveys much information about the actual willingness of consumers to substitute between the two as relative prices change. Not only is a salmon not a salmon to consumers, but our analysis on the cost of producing an additional salmon shows that the relative hatchery costs are much different. We will consider below the effect on a fisherman's net revenues of increases in each species.

Table Five: Comparison of current hatchery production levels with 15% increases and decreases in all hatchery produced stocks

(millions of pounds and millions of 1992 dollars)

Case 1: Current Level

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.77	7078.92	1700.36	0.00	1700.36
Cook Inlet	1702.43	1572.88	508.05	66.26	441.79
Kodiak	2425.80	1466.39	548.09	49.02	499.07
Prince Wm.	5215.02	2422.53	536.05	377.69	158.36
Southeast	6153.45	3534.28	1568.25	366.48	1201.76
State Total	23332.47	16075.00	4860.79	859.45	4001.34

Case 4(a): Increase all species by 15%

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.85	6957.94	1671.50	0.00	1671.50
Cook Inlet	1770.10	1574.82	509.85	73.03	436.81
Kodiak	2517.54	1450.53	541.22	61.31	479.91
Prince Wm.	5754.06	2456.17	543.22	409.11	134.11
Southeast	6423.49	3506.01	1547.67	425.29	1122.38
State Total	24301.03	15945.46	4813.45	968.74	3844.72

Case 4(b): Decrease all species by 15%

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Western AK	7835.69	7178.62	1724.08	0.00	1724.08
Cook Inlet	1635.65	1563.02	502.13	56.32	445.81
Kodiak	2336.98	1444.22	541.59	41.66	499.93
Prince Wm.	5117.45	2420.15	538.13	321.04	217.09
Southeast	5883.45	3462.62	1538.41	311.51	1226.90
State Total	22809.22	15068.62	4844.34	730.53	4113.80

Having given all of these caveats, let us consider the effect of either an increase or a decrease in the entire hatchery program. Data from Case 4a and 4b is compared with the current hatchery production levels in Table Five.

The results of Table Five can be summarized as follows. Either an increase or a decrease in all hatchery production by 15% will cause both revenues and producer's surplus to decrease. The decrease in revenues and producer's surplus is greater if the hatchery production increases (Case 4a) than if it decreases (Case 4b). If hatchery production increases by 15% for all species, then the estimated increase in hatchery costs is almost \$110 m. over thirty years. The increase in hatchery costs plus the decrease in producer's surplus means that relative to current hatchery output levels, an increase by 15% across the board would cause the state to lose \$156.62 m. (undiscounted) over thirty years, or about \$5.22 m. per year. If all hatchery production decreases by 15%, then producer's surplus is estimated to decrease by \$16.45 m. (undiscounted) over thirty years. However, hatchery costs are estimated to decrease by \$128.92, for a net increase of \$112.46 m. (undiscounted) over thirty years. Interestingly, about the only major distributional effect in producer's surplus has to do with Western Alaska, which stands to lose slightly less than a million dollars a year with an increase of 15% of all hatchery stocks and stands to gain less than a million a year with a decrease of 15%.

Again, we want to emphasize that neither of these alternatives are very appealing. The idea of an across the board increase or decrease ignores the fact that the effect of a change in the quantity of one species may be considerably different than for another species both for consumers and hence for ex vessel prices, and for production since hatchery costs are not identical across species.

Comparison of current hatchery production levels with 15% increases and decreases by species for hatchery produced stocks

We now turn to the consideration of changes in individual species. We find in net that a 15% increase or a 15% decrease of a particular species has a very small effect (less than 1%) on net benefits for all cases except pink salmon. Even for pink salmon a 15% increase or decrease in hatchery output has only about a 2% effect on net benefits. Although we have not calculated variance parameters for our estimates, it is likely that none of these is a statistically significant change from the current hatchery output levels. The summary data for the entire state is given in Table Six. We have not included regional data since the total effect is so small. However, this data can be found in Appendix One.

Table Six: Comparison of current hatchery production levels with 15% increases and decreases by species for hatchery produced stocks

(millions of pounds and millions of 1992 dollars)

	CATCH	REVENUES	SURPLUS	HATCHCOST	NET BENEFIT
Case 1					
current level	23332.47	16075.00	4860.79	859.45	4001.34
Case 7					
Increase Pink	23904.53	15997.97	4823.10	891.71	3931.39
Decrease Pink	22774.95	16126.83	4890.49	799.44	4091.06
Case 8					
Increase Red	23404.47	16105.51	4871.04	884.36	3986.68
Decrease Red	23260.40	16043.79	4849.71	843.55	4006.16
Case 9					
Increase Chum	23615.89	16136.18	4887.74	885.79	4001.95
Decrease Chum	23049.04	16006.04	4831.22	835.32	3995.90
Case 10					
Increase Coho	23357.68	16094.85	4868.94	869.71	3999.22
Decrease Coho	23305.74	16052.27	4851.17	852.18	3999.00
Case 11					
Increase King	23346.81	16102.67	4873.08	863.71	4009.37
Decrease King	23318.08	16047.68	4848.88	837.86	4011.01

A more interesting comparison is contained in Table Seven. There we calculate the change in producer's surplus resulting from either an increase or decrease in the quantity of salmon produced by the hatcheries. Our numbers suggest that on average, each pound of pink salmon provides between 5.3 and 6.6 cents of producer's surplus to fishermen. Recall our earlier estimate (Table Four) of the cost per pound to produce a pound of hatchery raised pink salmon was 5.6 and 10.8 cents per pound. Thus it appears that the cost per pound of producing pink salmon by hatchery production is greater than the producer's surplus it generates to fishermen.

This result seems to be true of red salmon also. Our estimate of the cost per pound to raise red salmon in hatcheries ranged from 22.1 to 34.6 cents per pound. However, our estimate of the average producer's surplus gained by this production is only 14.2 to 15.4 cents per pound. Before too much credence is placed on these numbers, however, it must be mentioned that our estimate of producer's surplus for red salmon is mainly from Bristol Bay (recorded as Western Alaska in our tables). Recall that our estimates for producer's surplus for Bristol Bay were made using average data from similar fisheries elsewhere in the state. We have no way of knowing how accurate these predictions are given that they are extrapolating well beyond the data available from fisheries elsewhere in Alaska.

Chum salmon also appears to have hatchery production costs that are roughly equal to the producer's surplus generated by an extra pound produced. We estimate that it costs between 8.5 and 9.3 cents to produce another pound of hatchery raised chum salmon, but fishermen receive producer's surplus of only about 9.5 to 10.4 cents per pound.

Coho is similar. Coho are estimated to cost between 27.2 and 40.7 cents per pound to produce, but generate producer's surplus on the order of between 32.3 and 36.0 cents per pound.

King salmon may be the best bet. If the marginal cost of king salmon based on an increase of 15% is accurate, then the cost of a king salmon is estimated to be about 29.7 cents per pound. Our estimate of the return in producer's surplus per pound of king salmon is between 82.8 and 85.7 cents per pound. However, if the marginal cost of king salmon based on a decrease is correct, then king salmon costs about \$1.50 per pound to produce. If this is true, then even king salmon fails to produce net benefits.

Table Seven: Estimates of producer's surplus created by an additional pound of salmon by species

(millions of pounds and millions of 1992 dollars)

	CATCH	SURPLUS	ΔCATCH	ΔSURPLUS	SURPLUS \$/LB
Case 1 Current level	23332.47	4860.79	****	****	****
Case 7 Increase Pink	23904.53	4823.10	572.06	37.69	0.066
Decrease Pink	22774.95	4890.49	-557.52	-29.70	0.053
Case 8 Increase Red	23404.47	4871.04	72.00	10.25	0.142
Decrease Red	23260.40	4849.71	-72.07	-11.08	0.154
Case 9 Increase Chum	23615.89	4887.74	283.42	26.95	0.095
Decrease Chum	23049.04	4831.22	-283.43	-29.57	0.104
Case 10 Increase Coho	23357.68	4868.94	25.21	8.15	0.323
Decrease Coho	23305.74	4851.17	-26.73	-9.62	0.360
Case 11 Increase King	23346.81	4873.08	14.34	12.29	0.857
Decrease King	23318.08	4848.88	-14.39	-11.91	0.828

Conclusions and Recommendations

Our results do not paint a very encouraging picture for the hatchery program. Based on our point estimates for the alternatives we believe our models were able to generate accurate results, the best alternative is to actually close the pink salmon hatcheries. However, we would not recommend that the state force all hatcheries to shut down. We would recommend that if a region wants to continue with a hatchery program, that it should be funded by the local user groups rather than by the state.

bad sentence

If the fishermen themselves fund the hatchery program, they will only choose projects which are cost-effective within their own region. There may still be regional effects in that production in one region causes prices to decline elsewhere, but whatever hatchery production remains will be cost effective. Table Eight compares the thirty year returns (undiscounted) for each alternative by region. Because we believe that our estimates of net benefits for Cases 2, 3, 4a, and 4b must be viewed with a great deal of caution, we separate them out in Table Eight.

Table Eight: Net Benefits by Region, By Alternative

(millions of 1992 dollars)

CASE	WESTERN	COOK INLET	KODIAK	PWS	SOUTHEAST	TOTAL
1	1700.36	441.79	499.07	158.36	1201.76	4001.34
5	1743.25	413.84	531.77	206.90	1565.88	4461.65
6	1779.38	413.77	422.60	201.97	1205.00	4022.72
7a	1694.53	443.16	485.68	152.87	1155.14	3931.39
7b	1706.17	439.39	506.20	182.35	1256.94	4091.06
8a	1689.54	441.46	506.79	157.25	1191.55	3986.68
8b	1711.29	437.49	488.84	166.35	1202.19	4006.16
9a	1698.72	441.04	494.97	155.98	1211.24	4001.95
9b	1702.31	442.96	498.74	158.16	1193.73	3995.90
10a	1698.45	440.36	498.31	157.17	1204.94	3999.22
10b	1701.52	444.58	499.33	157.63	1195.93	3999.00
11a	1699.54	443.07	498.68	157.80	1210.27	4009.37
11b	1701.42	448.25	506.80	158.31	1196.23	4011.01
2	1624.56	481.57	471.51	228.96	1151.24	3957.84
3	1918.84	467.50	533.37	229.91	1471.58	4621.20
4a	1671.50	436.81	479.91	134.11	1122.38	3844.72
4b	1724.08	445.81	499.93	217.09	1226.90	4113.80

The net benefit figures in each row of Table Eight are the returns for each region given that all regions are following the same hatchery production alternative. That is, for

the region to get the estimated net benefits listed for a particular alternative, every region has to be following the same alternative.

We have bolded the number in each column that corresponds to the best alternative for the region under the assumption that the region is financing its own hatchery program. In the subset of alternatives for which we express confidence in our net benefits estimates (Cases 1, and 5-11), alternative 5, shutting down the entire pink salmon hatchery production, is the best alternative for Kodiak, Prince William Sound, and Southeast. That is, if these regions could get the rest of the state to agree to following alternative 5, they would get the highest returns under a self-financed hatchery program.

The question is would the other two regions want also to follow alternative 5? While Western Alaska would benefit if the pink salmon program be shut down, their first preference would be that the red salmon hatchery production be shut down (Alternative 6). This is because red salmon dominates Western Alaska catch, so if everyone else shuts down red salmon hatchery production, Western Alaska red salmon prices rise at no additional cost to them. However, since Western Alaska only has one hatchery, and it produces only chum, it cannot independently influence the behavior of the other regions.

Cook Inlet is the odd one of the regions. Under a self-financing program, our estimates indicate that Cook Inlet would prefer everyone else shut down their king salmon programs. But since no other region will prefer this option, this alternative is not a feasible solution. If every other region is scaling back pink salmon hatchery production, Cook Inlet is made worse off relative to the current production levels. The question is could Cook Inlet by itself influence the actions of the other regions? The answer is probably, though not definitely, "no." The reason is this: Prince William Sound is producing currently 124 m. pounds of pink salmon. Cook Inlet is currently producing under 7 m. pounds, of which less than half comes from hatchery production. Thus, even if Cook Inlet felt that it could produce pink salmon at a net benefit to its fishermen, it is doubtful that it would have enough of an impact on prices to warrant the other regions changing their minds about scaling back their own pink salmon programs.

Notice that when Alternatives 2, 3, 4a and 4b are included, Kodiak, Southeast, Prince William Sound and Western Alaska all prefer shutting down either all of the pink salmon or shutting down the entire program. This suggests that if the hatcheries are to be self-financed, they will on their own choose to scale back their operations.¹⁰ Thus, we view turning over the financing of the hatcheries entirely to the regions as the best alternative to the state. The actions we predict the regions to take assumes that our point estimates are correct. If they are not correct, self-financing is still a better idea than continued state

¹⁰There may be a problem with the information gained by the hatcheries under a self-financing operation. Since the hatcheries generally take fish that are higher quality (because of less handling) and are cheap to harvest (because they are taken right at the hatchery), the price and cost information may be biased. However, as long as the fishermen themselves have a say in the quantity produced by the hatcheries, this bias should not be a problem.

funding because it makes the regions themselves decide what levels of hatchery production give them the highest returns.

If our recommendations are followed, hatchery production of fish for sport and subsistence purposes will most likely not continue without some state funding. We have made no effort to analyze the net benefits from hatchery production on other user groups. The way that we have calculated hatchery costs suggests that the same per pound costs obtained in our study are a reasonable approximation in the range of small changes in hatchery production to the hatchery costs for fish no matter what their use. To estimate more fully the benefits and costs to other user groups, the state would have to determine the net benefits to those groups.

There also may be some strategic reasons for maintaining some hatchery production. For example, it appears that hatchery exports of pink salmon may be starting in the former Soviet Union. Chile also appears to have room for expansion of its farmed salmon program. If these countries are able to produce fish less expensively than Alaska, then there will be no way to stop them from entering in the long run. However, by maintaining some hatchery production, prices may remain depressed enough to prevent expansions in those areas. As long as the price is not driven down to the level that it would reach if those areas do enter the market, the hatchery dollars spent on prevention of entry may be well spent. However, this is not a strategy which can remain viable over the long run.

There are a number of other things that the state might do with monies saved from the hatchery program. One obvious area is to engage in demand enhancing activities, such as increased attention to quality and seeking out new product forms. Again, we emphasize that if such activities are truly profitable, then the fishing industry itself should be willing to finance them rather than the state.

Another area that appears to be fruitful for future exploration is the allocation among gear groups. In the cost study we observed that the different gear groups have vastly different levels of producer's surplus. The gear group that does the best is the set net fleets. This is mainly because these fleets have such low capital costs. The bottom line is it is more efficient to let the fish come to the fisherman than to have the fisherman go to the fish.

Finally, let us re-emphasize that our estimates of net benefit are based on parameters estimated from relatively short time periods and were extrapolated well beyond the time horizon for which accurate estimates may be obtained. There are also a number of exogenous factors, such as what is happening in the rest of the salmon supplier's markets, that have changed far too rapidly over the last decade to allow precise estimates of where the industry will be in one, two or three decades. In spite of this, given our predictions of trends in the rest of the markets, we believe that the hatchery program, and especially the pink salmon program, should be scaled back. Our estimates suggest that to do so could result in an increase of net benefits to the state on the order of almost a half billion dollars over thirty years relative to current and planned production levels.

Overview of the Benefit-Cost Analysis of the Alaska Salmon Enhancement Program

Introduction

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Prompted by a request from the Alaska Board of Fish for additional policy direction regarding the management and allocation of enhanced salmon stocks, the Senate Special Committee on Domestic and International Commercial Fisheries initiated a review of the salmon enhancement program. This review included an economic benefit-cost analysis of the program. 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 was 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.

It is important to note that this review was by no means initiated as a result of legislative concerns regarding the overall management of Alaska's salmon stocks. Alaska's salmon fisheries are undoubtedly the most well managed in the world and the enhancement program is the most successful in the world. However, the enhancement program has been in place for over 20 years without an extensive review. In addition, after a decade of dramatic growth in international farmed-salmon production, world salmon markets and prices have been significantly altered. While Alaska's fisheries managers and the enhancement program are not the cause of these market changes, they and the commercial salmon fishing fleets must adapt to these changes to continue to be successful. In this light, the results of the economic review provide an opportunity to adjust fisheries management, enhancement, and marketing strategies to keep Alaska's salmon fisheries competitive. *

Methods

The benefit-cost analysis was conducted in four parts--a biological population/exploitation analysis, a international salmon demand analysis, a fishing cost analysis, and an enhancement production cost analysis. The results of these four parts were then combined for conducting the benefit-

cost analysis incorporating the public policy alternatives and sensitivity analyses.

The net benefits of the salmon enhancement program were ultimately measured by two variables. The first was the net benefits to fishermen from the hatchery program. This was determined by estimating the revenue to fishermen above their fishing costs that occurs under different hatchery production levels. Second, the cost of producing these benefits to fishermen, which is the cost of running the hatchery program, was estimated. Using the estimates of these two variables, the benefits of the program were calculated by taking the net benefits to fishermen minus the costs, including hatchery and the Alaska Department of Fish and Game, Divisions of FRED and Commercial Fisheries, of producing enhanced stocks.

As specified in the request for proposals, enhancement program benefits were estimated for seventeen different public policy alternatives. These alternatives included maintaining current production, increasing production to levels planned by hatchery operators, eliminating the entire program, eliminating pink salmon production, eliminating sockeye salmon production, and increasing/decreasing entire production or individual species production by 15 percent. These cases are shown in Table 1. In addition, for each of these alternatives, benefits were calculated using an optimistic (high price), pessimistic (low price), and mid-case sensitivity analysis. Net benefits were also calculated by fishing region. Therefore, for each public policy alternative, the "winner" and/ "loser" regions were identified.

Table 1. Program Alternatives Considered in the Policy Analysis

Case 1	Maintain current hatchery production
Case 2	Planned hatchery production levels
Case 3	Eliminate entire hatchery
Case 4a	Increase entire hatchery production level by 15%
Case 4b	Decrease entire hatchery production level by 15%
Case 5	Eliminate entire pink salmon production
Case 6	Eliminate entire sockeye salmon production
Case 7a	Increase pink salmon hatchery production level by 15%
Case 7b	Decrease pink salmon hatchery production level by 15%
Case 8a	Increase sockeye salmon hatchery production level by 15%
Case 8b	Decrease sockeye salmon hatchery production by 15%
Case 9a	Increase chum salmon hatchery production by 15%
Case 9b	Decrease chum salmon hatchery production by 15%
Case 10a	Increase coho salmon hatchery production level by 15%
Case 10b	Decrease coho salmon hatchery production by 15%
Case 11a	Increase king salmon hatchery production by 15%
Case 11b	Decrease king salmon hatchery production by 15%

Assumptions and Limitations of the Analysis

While this benefit-cost analysis is rigorous and incorporates the most extensive international salmon demand model developed to date, there are limitations to the modeling capabilities and the scope of the study. First, the analysis only measures the direct benefits of the program. Indirect and secondary benefits to communities such as fish processing employment and other indirect activities are not measured. The analysis excluded program benefits (and costs) to the sport and subsistence fisheries. Therefore, this study should be considered a partial analysis of the program.

Second, the demand analysis uses quarterly data from 1982 to 1991. The fishing cost analysis was done using only 1990 data. Projections for 15 or 30 years based on these relatively short time series are risky. In addition, the salmon demand model analyzes pink and chum demand together as "low-valued species" and sockeye, coho, and king together as "high-valued species." As a result of these aggregations, the cross-price effect within the groups (the effect changes in pink production has on chum prices, for example) are overstated, and revenues assigned to cases 2, 3, and 4a will be understated. The results for these cases should be considered a worse case scenario.

Abstract *production study*
It would be
difficult to
accurately
assess the
impact of
these
factors.
They could
be
significant

Third, the production levels under each of the "elimination" alternatives (Cases 3, 5, and 6) are vastly different from the production levels in the historical time period used to estimate the demand and cost models. Therefore, especially for Cases 3 and 5, the models were forced to extrapolate well beyond the data in the analysis which could result in prediction of prices above their historical levels. As a result, the "elimination" alternatives should be viewed as a worse case scenario (e.g., benefits of eliminating the entire program or parts of the program may be overestimated). In other words, all of the most drastic public policy alternatives results should be considered worse case scenarios.

Fourth, fishing cost modeling efforts were limited to a representative sample of commercial fishing gear types across the regions of the state (Prince William Sound seine and drift net, Cook Inlet seine and drift and set net, Kodiak purse seine and set net, and Southeast power and hand troll). The gear-type specific modeling parameters of these efforts were then extrapolated to other fisheries in the state. To the extent to which fishing costs vary between regions, fishing cost estimates may be inaccurate. **These caveats imply that the results of the analysis should be interpreted and applied cautiously.**

Results

This section provides the results of the policy alternative simulation. A discussion of the implications of these results are in the following section.

Under current hatchery production levels (Case 1), the direct net benefits of the Alaska salmon fishery were estimated to be \$109.71 million in 1992. The annual net benefits were projected to rise steadily in real (1992, inflation adjusted) dollars over the 30-year planning horizon. Over the 30-year period, the researchers estimated that the salmon fishery with hatchery production at current levels would bring in \$4.0 billion in net benefits (\$2.3 billion in present value discounted at a 4% discount rate) to the Alaska economy on revenues of \$16.1 billion. The difference between gross revenues and net benefits were hatchery costs (\$859 million) and fishing costs (\$11.2 billion). These results are based on the midpoint price estimates of the salmon demand model.

Table 2 shows the estimated total and regional net benefits of the Alaska salmon fishery under current hatchery production as well as the 16 other policy alternatives. Western Alaska includes the Bristol Bay salmon

fisheries and is net of fishing costs; hatchery costs for the region are zero. All regions of the state are included in the analysis regardless of the level of enhanced production because salmon production levels in one region affect salmon prices and, thus, revenues and net benefits in other regions.

Table 3 and Chart 1 show the change in estimated total and regional net benefits over the 30-year period of altering enhanced salmon production from current levels. The **largest increases** in potential net benefits result from 1) eliminating the entire program (Case 3, \$619.9 million increase), 2) eliminating the pink program (Case 5, \$460.3 million increase), 3) decreasing the entire program production by 15% (Case 4b, \$112.5 million increase), 4) decreasing the pink program production by 15% (Case 7b, \$90.7 million increase), and 5) eliminating the sockeye program (Case 6, \$21.4 million increase).

The **largest decreases** in potential net benefits resulted from 1) increasing enhanced production by 15% (Case 4a, \$156.6 million decrease), 2) increasing pink production by 15% (Case 7a, \$70.0 million decrease), 3) increasing production to planned levels (Case 2, \$43.5 million decrease), and 4) increasing sockeye production by 15% (Case 8a, \$14.7 million decrease). For the most part, 15% production changes from current production levels of chum, coho, and king salmon have relatively small changes in program net benefits.

Other significant results include:

- farmed salmon is a perfect substitute for the higher-valued Alaska salmon species (chinook, coho, and sockeye),
- expansion of sockeye salmon enhanced production would not result in increases in total net benefits primarily because of offsetting losses in Western (primarily Bristol Bay) and Southeast Alaska, and
- similarly, increasing production to levels the hatcheries currently "plan" would result in net losses because of losses in Western, Kodiak, and Southeast Alaska.

Discussion

As noted by the study's researchers, these are not encouraging results for the Alaska salmon enhancement program. In general, these results are caused by three primary factors--price elasticities, the cost of producing

enhanced stocks, and the cost of fishing. First (in economic jargon), the price elasticities for Alaska salmon are approaching unitary elasticities. This means that for a 1% increase in price, a 1% decrease in revenue occurs (or visa versa). **This suggests that there is sufficient supply in current Alaska salmon markets and any increase in supply will tend to decrease prices.**

In addition, it appears that enhanced stock production costs and fishing costs are at best marginally covered under currently depressed ex-vessel fish prices, especially for pink salmon. It is unlikely that the situation could be sustained without continued state subsidies such as salmon enhancement loans. For example, the research estimates that the average cost of the pink salmon hatchery program is roughly 10.3 cents per pound. Given that fishermen could not afford to fish with prices at 12.1 cents per pound (research results for Prince William Sound), it suggests that pink salmon prices have to be over 22.4 ($=10.3+12.1$) cents per pound before hatchery fish production is profitable. Note, for example, that Case 4a in Table 3 (15% increase in enhanced pink salmon production) results in net revenue losses even in Prince William Sound.

Government subsidies tend to insulate an industry or a portion of industry activity from market signals. For example, the salmon enhancement loan program lowers the cost of enhanced salmon production. This may encourage expansion of production beyond sustainable levels given world salmon prices, especially if loans are used to fund operating costs as well as capital costs. Subsidies can also discourage quick response to rapidly changing market conditions. **It is possible that the results of this analysis are so dramatic because the enhancement loan program has unintentionally insulated the hatcheries from the markets they serve. These factors should be kept in mind so the state does not merely shift from subsidizing production to subsidizing marketing efforts.**

There are two critical considerations regarding these results. First, the **benefit-cost analysis assumes that the benefits from shifting output or reducing enhanced salmon production can be captured by the Alaska fisheries.** In reality, a decrease in Alaska's enhanced production may result in increased salmon prices. These increased prices may, in turn, allow for the expansion of farmed-salmon production which would dampen the price increase and absorb Alaska's vacated market share.

As noted by the study's researchers, **this may provide a strategic reason for maintaining some level of enhanced production.** Hatchery exports of pink salmon production may be starting in the former Soviet Union and Chile appears to have room for expansion of its farmed-salmon program. If these countries are able to produce fish less expensively than Alaska, it is impossible to prevent them from entering in the long-run. However, by maintaining hatchery production, prices may remain depressed and prevent or postpone market entry. As long as prices are not depressed to the level that would result from the farmed-salmon production market entry, the dollars spent to prevent the entry may be well spent. This is a short-run strategy, however, that would not be viable over the long run.

The other important consideration is that the benefit-cost analysis assumes that the international salmon markets continue to reflect the characteristics of the study period---1982 through 1991. While this can be viewed as a weakness of economic analyses, in this study it shows the bleak future for Alaska salmon fisheries, regardless of whether they are enhanced or wild stocks, if market expansion and changes do not occur. Efforts are currently underway to develop new pink salmon products lines and to pre-sale cost-recovery harvests. Increased attention to market development rather than increased production is in the best interest of the industry.

Options

- While the research results suggest either eliminating the entire enhancement program or the entire pink salmon program as a mechanism for maximizing net benefits, either of these actions would have significant impacts on Alaska's coastal communities, especially in Prince William Sound. These options should not be considered without more analysis of the sport and subsistence fishing benefits and indirect benefits of the program.
- Impose a moratorium on ADF&G permits on new or increased enhanced production of pink salmon stocks.
- Impose a moratorium on enhancement loans for new or expansion of pink production capacity.
- Restrict the use of salmon enhancement tax and cost recovery funds for new or expansion of pink production capacity.