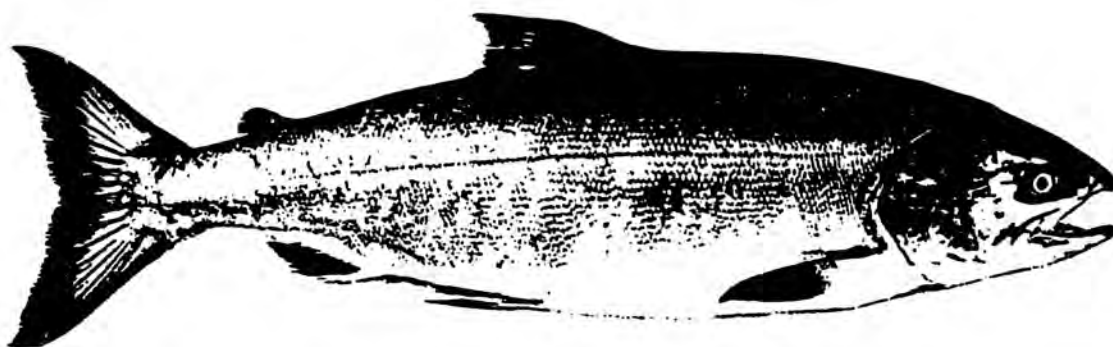


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**LEGISLATIVE REVIEW
OF THE
ALASKA SALMON
ENHANCEMENT PROGRAM**

DRAFT CHAPTER IX - ECONOMICS



**Alaska State Senate
Special Committee on
Domestic & International Commercial Fisheries**

JANUARY 1993

PREFACE

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

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

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

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

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

On February 24, 1992, the Committee held a statewide teleconference to hear public comment on the draft report. The hearing produced several hours of testimony and discussion. Many individuals and groups also submitted written comments to the Committee. The public comments have been made available to the Legislature, and are included in the appendices to the final report, which are available from the legislative library in Juneau.

The University of Alaska's work on the economic studies took more time than originally anticipated. The benefit-cost analysis was not completed until the end of December 1992. Because the Committee is a temporary, special committee established only for the duration of the 17th Legislature, it was not possible to hold public hearings on the economic portion of the review project. *Since the economics chapter has not had the same public review that the rest of the chapters have received, the Committee decided to publish it*

separately in "draft" and make it available to the public at the same time as the final report. It should also be clearly understood that the economic benefit-cost analysis is solely the product of the university researchers who authored it under contract. The Committee, the Alaska Department of Fish and Game, and the Commercial Fisheries Entry Commission have not taken a position on any of the study's findings. Simultaneous with the release of this draft chapter to the public, an independent, third-party economic review is being initiated through the Commercial Fisheries Entry Commission of the methodology, computer models, and data used in the benefit-cost analysis.

An important product of the economic research conducted by the University of Alaska Fairbanks is the development of a highly technical computer model for use in analyzing the benefits and costs of enhancement efforts. This model will provide the basis for ongoing benefit-cost analyses of the enhancement program in the future. Over time, the level of confidence in the results will increase as additional data are developed. The Committee will provide the model and back-up information to the Alaska Department of Fish and Game for future use.

The final report of the review project, the following draft chapter on economics (which includes the benefit-cost analysis), and the mailing list of those who have expressed interest in this project are being submitted to the 18th Alaska Legislature. A letter accompanying the two documents requests that public hearings be held on the draft economics chapter, and that those on the mailing list be notified of such hearings.

It is the hope of the Senate Special Committee on Domestic and International Commercial Fisheries that the final report and the following draft chapter will be used as guidelines as the Legislature and all those interested in Alaska's fisheries enhancement efforts work together to make sound policy decisions regarding this important program.

Chapter IX ECONOMICS

A. Introduction

One of the goals of the Senate Special Committee on Domestic and International Commercial Fisheries in its review of Alaska's salmon enhancement program was to examine the overall economics of the state's enhancement efforts. The Committee hoped to provide information that would assist policy-makers in achieving optimal net benefits to the state in the future by adjusting fisheries management, marketing strategies, enhancement production levels and species mix, and the levels of state funding of enhancement efforts.

A review of existing economic research revealed that insufficient economic information was available to address these issues, and that developing such data would require highly sophisticated computer modeling programs. *While one study could not include all economic aspects of the enhancement program, a direct benefit-cost analysis approach was selected, and key questions were framed for this initial study.* The Committee, the Alaska Department of Fish and Game, and the Commercial Fisheries Entry Commission worked together to see this study accomplished. However, none of the three entities has yet taken a position on the study's findings.

B. Overview of the Benefit-Cost Analysis of the Alaska Salmon Enhancement Program to Commercial Fisheries

Project Background and Methodology

The biological and economic research for the benefit-cost analysis was to be conducted under contract through Reimbursable Services Agreements (RSA).. A request for proposals was developed in consultation with the Department of Fish and Game (ADF&G) and the Commercial Fisheries Entry Commission (CFEC), and submitted to interested researchers in Alaska. Researchers at the University of Alaska Fairbanks (UAF) were selected based on their professional expertise and experience.

As stipulated in the contract, the benefit-cost analysis looked at 17 hypothetical scenarios, including various levels of increased and decreased production of the different salmon species. These were all compared to the potential benefits of maintaining current levels of enhanced production into the future. The period of analysis was the 30-year period 1992 - 2021. The study made no assessment of the value of the enhancement program prior to 1992.

The benefit-cost analysis was conducted in four parts--a biological population-exploitation analysis (Collie, 1992), an international salmon demand analysis (Herrmann and Greenberg, 1992), a fishing cost analysis (Boyce, 1992), and an enhancement production cost analysis [a cooperative effort of legislative staff, the Legislative Research Agency, the Alaska Department of Fish and Game (ADF&G), Division of Fisheries Rehabilitation, Enhancement and Development (FRED)]. The results of these four parts were then combined for conducting the benefit-cost analysis incorporating public policy alternatives and sensitivity analyses (Boyce, Herrmann, Bischak, and Greenberg, 1992).

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The research required a considerable volume of data. Biological data on Alaska fisheries were provided by ADF&G. Ex-vessel prices, permit and earnings data on Alaska salmon fisheries were provided by CFEC. International market and fisheries data for the rest of the United States, Japan, Europe, Canada, and Chile were obtained by the researchers. Enhancement program management and administrative costs were developed by ADF&G, Divisions of Commercial Fisheries and FRED. In providing oversight, Committee staff worked closely with ADF&G during all phases of the research project.

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

Assumptions and Limitations of the Analysis

The benefit-cost analysis was rigorous and incorporated the most comprehensive international salmon demand model developed to date. However, there were limitations to the modeling capabilities and the scope of the study, and simplifying assumptions were made to make an extremely complex project more manageable (something done in every analysis of this type).

First, the analysis only measured the direct benefits of the program to commercial fishermen. Indirect impacts to communities such as fish processing employment and income and other indirect activities were not measured. The analysis also 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 used 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 analyzed 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 had on chum prices, for example), and case 4b revenues, were overstated, and revenues assigned to cases 2, 3, and 4a were understated. *The results for these cases should be considered worst case scenarios, and may have too little certainty to warrant consideration.*

Third, the production levels under each of the "elimination" alternatives (cases 3, 5, and 6) were 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 worst case scenarios (e.g., benefits of eliminating the entire program or parts of the program may be overestimated), and again, results may be too uncertain to warrant consideration.*

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,

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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.*

Fifth, *it was assumed that Alaska's wild production would remain at the high levels seen in the last ten years.* It would be helpful to use the model in the future to analyze production with lower wild production levels. The latter would parallel conditions under which the enhancement program was developed 20 years ago, and would reflect a range of production levels that might occur in the future.

Sixth, a benefit-cost analysis addresses economic *efficiency* criteria which relate to the value of resources, such as a salmon fishery. *There are factors other than economic efficiency to be considered when developing public policy.* For example, a fishery enhancement project in a rural area of Alaska with chronic unemployment might be a desirable project, even if it does not produce positive net benefits for the state as a whole.

And finally, it should be stressed that *all of the study's benefit-cost analytical results were point estimates. No confidence intervals were calculated because of the complexity of the models, so there is no way to judge if the changes in net benefits, as calculated, are statistically significant.*

Results

Table 1 contains the production alternatives requested in the contract. Table 2 shows the estimated total and regional net benefits of the Alaska salmon fisheries under current enhanced production as well as the 16 other production alternatives. Western Alaska includes the Bristol Bay salmon fisheries and is net of fishing costs; enhanced production costs for Western Alaska region are zero. All regions of the state were included in the analysis regardless of the level of enhanced production in order to examine whether salmon production levels in one region affect salmon prices and, thus, revenues and net benefits in other regions.

Table 3 shows the change in estimated total and regional net benefits over the 30-year period under the various levels of altering enhanced salmon production from current levels. Again, it must be emphasized that without confidence intervals, the significance of the results in Tables 2 and 3 is unclear. With the exception of pink salmon and possibly sockeye salmon, the model developed under this contract does not seem to discern any significant changes in net benefits using the 15% production increase or decrease scenarios.

The elimination scenarios did result in a significant increase in net benefits. However, given the complexity of the model, the lack of confidence intervals, and the limitations of the analysis, these results can not be accepted with certainty. The researchers were not asked to analyze additional mid-case scenarios such as 30, 45, 60, or 75% increases or decreases. Further analysis along these lines would be useful, as would further analysis of the effects of high/low cycles of wild stocks on the net benefits of the enhancement program.

C. Discussion of Findings

While it is difficult to interpret the actual quantitative results of the study with certainty, the models developed under this contract are very sophisticated and provide valuable information on Alaska's salmon fishery. In addition, ADF&G will have access to these models, so they will continue to be a source of information on the enhancement program and Alaska's salmon

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fisheries. With some relatively minor changes, these models can also be used for analyzing information on all of Alaska's salmon program, including wild salmon harvests.

The following describes the report's most important findings:

- *None of the 15 percent differences in enhanced production changed the estimated present value of net benefits by more than \$45 million (accumulated over 30 years). These changes must be compared to the net benefits from maintaining current production levels which are estimated at nearly \$2.4 billion (accumulated over 30 years).* As a practical matter, the model outputs have enough uncertainty associated with them that we cannot say that actual benefit changes would necessarily be different from zero.

- *Current pink salmon production levels may be too high.* For example, complete elimination of pink salmon production increased the present value of net benefits by \$147 million (accumulated over 30 years), or by nearly 6 percent from current overall salmon production. Again, it is difficult to say with a high level of confidence that the actual change would be significant. However, the large size of the benefits for the elimination of the pink salmon program option, and its consistency with the 15 percent incremental results for pink salmon, make this result more suggestive than the others. It is probable that if supply and demand market conditions do not change in the future, revenues from additional enhancement of pink salmon would be negative. In addition, *the findings suggest that production of sockeye salmon has also approached a level where statewide revenue gains from increased production will be small.* This is primarily due to the relatively high cost of producing sockeyes and the offsetting losses in fish prices in Western (primarily Bristol Bay) and Southeast Alaska.

These conclusions stem from specific factors present during the period analyzed: world salmon supplies were at record levels; farmed salmon production increased from zero to almost one-third of the world's salmon production; and Alaska's wild stock production was at record high levels.

- *Changes in enhanced production in one region of the state may have significant positive and negative impacts on the revenues of other salmon-producing regions of the state through their effects on market prices.* Thus, the revenue gain by salmon fishermen in one region may be offset by a revenue loss in another region or statewide.

The researchers' individual models, which were used to develop the actual benefit-cost analysis, also contain significant findings, although it is unknown at this time how these findings affect the overall net benefits of the salmon enhancement program:

- *Small changes in supplies of wild or farmed salmon have a price-depressing effect on Alaska fisheries than previously reported in other research on salmon demand.* Thus, under the historical time series tested in the international market demand model, a more acute reduction in price occurred than expected when Alaska's own fishermen had larger harvests.

- *The additional costs to fleets from catching more fish are a significant cost of the statewide fishery enhancement program. The costs found by the researchers are higher than those assumed in many benefit-cost analyses of fishery enhancement projects in Alaska.* In some fisheries, these factors significantly

reduce the potential for creating additional producer surplus. Currently, Alaska fishing regulations are developed without explicit regard to the economic impacts of these regulations on fleet fishing costs. If Alaska's salmon industry is to remain competitive with farmed-salmon production, more attention to developing cost-effective regulations, while maintaining fish stocks, will be needed.

- The demand model indicates that *farmed salmon is a fairly close market substitute for the higher-valued Alaska salmon species (chinook, coho, and sockeye).*

- *Increasing production to levels currently planned by the enhancement facilities appears to result in net losses statewide because of losses in Western, Kodiak, and Southeast Alaska¹.*

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.* While a decrease in Alaska's enhanced production may result in increased salmon prices, increased prices may, in turn, allow for the expansion of farmed-salmon production worldwide. Expansion of farmed-salmon would most likely dampen the price increase and absorb Alaska's vacated market share. As noted by the researchers, *this may provide a strategic reason for maintaining some level of enhanced production.* Hatchery exports of pink salmon production may be forthcoming from 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 the marketplace in the long-run. However, by maintaining enhanced production levels in Alaska, 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 will continue to reflect the characteristics and trends of the study period of the demand analysis---1982 through 1991. While this can be viewed as a weakness of economic analyses, in this study it shows the difficult future for Alaska salmon fisheries, regardless of whether they are enhanced or wild stocks, if industry does not expand its market share. In response to this challenge, efforts are currently underway to develop new pink salmon product lines and to pre-sell cost-recovery harvests.

Important as they are, the results of a benefit-cost analysis are only one of several factors that should be considered when making enhancement policy. Other questions are important as well. For example, do enhancement expenditures give the state the "biggest bang for its buck" in generating employment or personal income? How does the pattern of enhancement expenditures fit in with the state's regional development policy? What is the impact of the hatchery program on local and state governments? The answers to these questions must be considered as part of any overall analysis of the benefits of the program.

¹ The "planned" production level was by far the largest catch level tested and represented the level of production at which operators, when surveyed, said they would like to be permitted and funded.

Options for possible consideration

As noted in the chapter preface, the benefit-cost analysis has not yet undergone extensive professional peer or public review. Although possible policy options were included in other chapters in the main report, it was considered premature to formulate options for this chapter until further review confirms the validity of the study results.

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%

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Table 2. Net Benefits of the Alaska Salmon Fisheries with Changes in Enhanced Production by Region and Production Alternative, 1992-2022
(millions of 1992 dollars, discounted at 4%)

Policy Alternative	Case #	Western Alaska	Cook Inlet	Kodiak	Prince William S.	Southeast	State Total
Current Production	1	993.40	276.55	288.69	126.63	737.78	2,423.05
Eliminate Pink Prog.	5	1,016.91	271.01	312.64	95.02	874.81	2,570.39
Eliminate Sockeye Prog.	6	1,036.43	284.07	258.72	119.11	754.07	2,452.41
Increase Pink 15%	7a	990.19	277.31	281.15	116.59	712.88	2,378.12
Decrease Pink 15%	7b	996.61	276.73	293.54	131.11	758.86	2,456.85
Increase Sockeye 15%	8a	987.77	276.36	292.62	126.74	724.09	2,407.57
Decrease Sockeye 15%	8b	999.17	277.54	284.79	126.65	740.23	2,428.38
Increase Chum 15%	9a	992.53	276.15	286.22	123.13	736.14	2,414.18
Decrease Chum 15%	9b	994.43	276.92	289.33	126.07	726.29	2,413.04
Increase Coho 15%	10a	991.88	275.69	288.26	130.46	734.24	2,420.54
Decrease Coho 15%	10b	994.02	276.82	289.03	126.11	735.76	2,421.73
Increase King 15%	11a	992.97	277.32	288.49	130.77	736.89	2,426.44
Decrease King 15%	11b	993.94	276.81	288.90	126.69	732.94	2,419.27
Planned Production	2	955.09	296.22	274.52	157.15	713.85	2,396.84
Eliminate Program	3	1,109.59	288.91	309.48	144.29	863.69	2,715.95
Increase all 15%	4a	978.03	274.76	277.56	114.16	674.43	2,318.94
Decrease all 15%	4b	1,005.97	278.71	288.60	145.08	736.28	2,454.63

Source: Boyce, et al. "A Benefit-Cost Analysis of the Alaska Salmon Enhancement Program," December 1992.

Table 3. Changes in Net Benefits of the Alaska Salmon Fisheries with Changes in Enhanced Production by Region and Production Alternative, 1992-2022
(millions of 1992 dollars, discounted at 4%)

Policy Alternative	Case #	Western Alaska	Cook Inlet	Kodiak	Prince William S.	Southeast	State Total
Eliminate Pink Prog.	5	23.51	-5.54	23.95	-31.61	137.03	147.34
Eliminate Sockeye Prog.	6	43.03	7.52	-29.97	-7.52	16.29	29.36
Increase Pink 15%	7a	-3.21	0.76	-7.54	-10.04	-24.90	-44.93
Decrease Pink 15%	7b	3.21	0.18	4.85	4.48	21.08	33.80
Increase Sockeye 15%	8a	-5.63	-0.19	3.93	0.11	-13.69	-15.48
Decrease Sockeye 15%	8b	5.77	0.99	-3.90	0.02	2.45	5.33
Increase Chum 15%	9a	-0.87	-0.40	-2.47	-3.50	-1.64	-8.87
Decrease Chum 15%	9b	1.03	0.37	0.64	-0.56	-11.49	-10.01
Increase Coho 15%	10a	-1.52	-0.86	-0.43	3.83	-3.54	-2.51
Decrease Coho 15%	10b	0.62	0.27	0.34	-0.52	-2.02	-1.32
Increase King 15%	11a	-0.43	0.77	-0.20	4.14	-0.89	3.39
Decrease King 15%	11b	0.54	0.26	0.21	0.06	-4.84	-3.78
Planned Production	2	-38.31	19.67	-14.17	30.52	-23.93	-26.21
Eliminate Program	3	116.19	12.36	20.79	17.66	125.91	292.90
Increase all 15%	4a	-15.37	-1.79	-11.13	-12.47	-63.35	-104.11
Decrease all 15%	4b	12.57	2.16	-0.09	18.45	-1.50	31.58

Source: Boyce, et al. "A Benefit-Cost Analysis of the Alaska Salmon Enhancement Program," December 1992.

A BENEFIT-COST ANALYSIS OF THE ALASKA SALMON ENHANCEMENT PROGRAM

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Final Report

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The views expressed and all remaining errors are the sole responsibility of the authors.

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EXECUTIVE SUMMARY

When the enhancement program in Alaska was initiated in the early 1970s, Pacific salmon dominated world salmon markets. Since then, there has been a rapid rise in the supply of salmon worldwide. In Alaska, this has been in large part due to production from the enhancement program, in which the state has invested considerable funds, combined with significant increases in wild stocks. The worldwide increase in production is primarily the result of large increases in farmed-salmon production. It appears that supplies of salmon on the world market are more likely to continue to increase than to decrease.

Given this backdrop, the Alaska Legislature's Senate Special Committee on Domestic and International Commercial Fisheries contracted for a cost-benefit analysis as part of its review of the enhancement program. Concerns have also been raised regarding the differential regional impacts of the program. This report summarizes the findings of the study. The results of this analysis are intended to assist policy makers in their deliberations regarding the level of continued state support of the program. The study should also be useful to regional aquaculture associations in planning future enhancement activities.

This analysis used a state accounting stance, which means that only the benefits and costs occurring in Alaska were considered. Thus, for example, the benefits to consumers in other parts of the U.S. or in other world markets were not considered. In addition, the analysis makes no attempt to discern whether fishermen benefiting from the enhancement program were residents or nonresidents. It should be noted that this study followed traditional benefit-cost analysis methods, and focused on the aggregate benefits and costs to commercial salmon fishermen. Benefits and costs to other user groups, such as sport fishermen, the growing charter boat industry, and subsistence fishermen were not included. In addition, indirect impacts such as employment and income from fish processing, were not included. In order to ultimately draw conclusions and make policy concerning the future of the salmon enhancement program, all of these additional factors must be considered.

The period of analysis is the 30-year period 1992 - 2021. The study analyzed changes in net benefits given alternative future production levels. It made no assessment of the value of the enhancement program over the past 20 years.

Many of the variables upon which these models have been built are difficult to predict and must be continually updated and verified. The models have been provided to the Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, & Development (FFED) for future analyses.

The benefit from the enhancement program used in this model is the *producers' surplus*, which is the return to fishermen above their variable fishing costs. The cost of producing the surplus for fishermen is the cost of producing the enhanced stocks of salmon. The net benefits of the enhancement program are the producers' surplus minus the costs of operating the hatchery program.

The economics study consisted of four parts. First, a biological model (Collie, 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 producers' surplus in each fishery given the ex-vessel prices and returns of fish from the biological model (Boyce, 1992)¹. Finally, a survey of the hatcheries revealed the costs of producing various levels of hatchery fish.

Research Objectives and Methodology

The request for proposals outlined 17 alternatives. These production alternatives are described in the first column of Table One. Each alternative was to be considered over a 30-year planning horizon. Given the trends in demand and supply 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.

As in any modeling exercise, there were a number of assumptions that enter into the model. The relative value of changes in enhanced salmon production in Alaska are accurate only so long as relative *trends* in international salmon markets remain unchanged.

Future values of the following variables were estimated using linear trends on the basis of observed 1983 to 1991 growth rates---

- population of the EEC, 0.32% annual growth rate;
- population of Japan, 0.43% annual growth rate;
- population of the United States, 0.92% annual growth rate;
- the "real" food consumption expenditure in Japan, 0.29%;
- the "real" United States personal disposable income, 3.0% annual growth rate; and
- the "real" private consumption expenditure in EEC, 2.9%.

Future values of the following variables, as well as consumer price indexes and tariffs, were held constant at 1992 levels as is usual practice in benefit-cost analysis---

- European Currency Unit (ECU)/U.S. exchange rate, 0.7968;
- Norwegian kroner/U.S. dollar exchange rate, 6.3549;
- Japanese yen/U.S. dollar exchange rate, 129.50;
- Norwegian kroner/Japanese yen exchange rate, 0.0491; and
- Norwegian kroner/ECU exchange rate, 7.9755.

In addition, there are a number of limitations to the modeling exercise. Among the more important are the following:

- Predictions are based on models using data from only a small number of years.
- All of our analysis is based on point estimates. We have not constructed confidence intervals for our estimates.
- The production levels under each of the elimination alternatives are vastly different than the production levels we observed in the historical time period used to estimate our demand and fishing cost models.
- There are no empirical estimates of cross-price effects between species within aggregate groupings of high and low valued species.

¹Copies of these reports, as well as additional data output files from this report, are available at the Legislative Library in Juneau.

- The estimated producers' surplus are "surplus above variable opportunity costs," which do not include fixed costs such as vessel and license costs.
- Simulations of the fishing costs for future years assumed that the season returns behaved as an inflation or a contraction of the returns in 1990.
- Fisheries for which fishing costs were not explicitly estimated used fishing costs based on the average fishing costs for fisheries with similar fleets.
- The simulation estimates for the final 15 years of the 30-year planning horizon are the simple averages of the 10th through 15th years.
- Enhancement costs associated with "cost recovery" are revenues to the fishermen catching those fish, and are not included in enhancement costs.

Alternatives 2-4 are separated in the analysis that follows because these cases involve such large changes from the historical data that the revenue estimates are likely to be inaccurate.

Comparison of Alternatives

Tables One, Two, and Three summarize our findings. Table One shows the statewide total catch, total gross revenues, producers' surplus, enhancement costs, and net benefits estimates for the 30-year planning horizon. The dollar figures are all present value (1992 dollars), with future benefits discounted at 4%. Table Two shows the net benefit figures for each region. Table Three shows the cost and benefits per pound of enhanced production by species.

The enhancement program's effect on catch is large. Under current hatchery production (case 1), output over the next thirty years is projected to be 23,333 million (m.) pounds, or 778 million pounds per year. If the entire hatchery program was to be eliminated (case 3), output would drop to 16,802 million pounds over the 30-year planning horizon, or to 560 million pounds per year. The hatchery program is thus responsible for approximately 28% of Alaska salmon production. The pink salmon enhancement program is considerably larger than all other programs. Elimination of the entire pink salmon program would reduce total catch by 16.6% from current levels. By comparison, elimination of the red salmon program would only reduce total catch by 2.2% from current levels. The other species are even less important in terms of total output.

There are regional differences in the production levels of the enhancement program. Western Alaska produces only small amounts of king, coho, and chum salmon and no pinks or reds. Cook Inlet has approximately 20% of its production from enhanced pink salmon, with an additional 6% of its production from enhanced red salmon. Cook Inlet also produces small amounts of king, coho, and chum salmon. Kodiak has about 12% of its current production from enhanced pink salmon, and an additional 7% from enhanced red salmon. Kodiak also produces smaller amounts of each of the other species. Prince William Sound has about 42% of its total catch from enhanced pink salmon. An additional 4% of the current total catch comes from enhanced red salmon, and an additional 7.5% from enhanced chum salmon. Small amounts of king and coho are also produced in Prince William Sound. Southeast receives 3.7% of its current production from enhanced chum salmon, about 3.8% from enhanced pink salmon, about 1.4% from enhanced king salmon, about 2% from enhanced coho salmon, and about 0.5% from enhanced red salmon. Of all the regions, Prince William Sound is most dependent upon enhancement for its current production levels. Western Alaska is the least dependent.

Proportional increases in catch do not imply proportional increases in revenues. Revenues depend upon both quantities and prices. Since increases in quantities cause prices to decrease, revenues may either increase or decrease as quantities decrease. The revenue effect of the enhancement program can be seen by comparing the current levels (case 1) with the elimination of the entire program (case 3). The enhancement program produces revenues over 30 years worth approximately \$390 million today.

If revenues rise because a price increase more than offsets a decrease in catch, then the increase in revenues will be accompanied by a decrease in costs. This is superior to a case where revenues increase, but costs also increase. This can occur if the increase in catch is more than offset by the corresponding decrease in price. Alternatively, revenues may decrease if prices fall sufficiently while fishing costs increase as a result of the increased harvest. These examples suggest that net benefits to fishermen as measured by producers' surplus is a better measure of fishermen's welfare than changes in gross revenues.

The effects of the different alternatives on fishermen are considerably dampened when producers' surplus is used as the measure rather than total revenues. Producers' surplus is about 30% of total revenues for most of the alternatives. The difference in the 30-year present value between the highest (case 5, elimination of pink salmon) and lowest (case 3, elimination of all the hatchery program) producers' surplus values is \$143.2 million. This is substantially smaller than the \$422.7 million difference in present value between the highest- (case 9a) and the lowest-valued (case 3) gross revenue alternatives.

The elimination of the entire program and of the red salmon enhancement program (cases 3 and 6) each cause statewide producers' surplus to decrease. However, the elimination of the pink salmon program (case 5) causes statewide producers' surplus to increase. Producers' surplus in Western Alaska increases if any of the programs are eliminated.² In Cook Inlet and Prince William Sound, producers' surplus decreases if any part of the program is eliminated. Producers' surplus in Kodiak increases only if pink salmon enhancement is eliminated (case 5); Southeast gains if either program is eliminated individually, but loses if both are eliminated (case 3). This effect on Southeast Alaska is probably due more to technical difficulties with the case 6 simulation than to a depiction of what would actually occur.

We estimate the costs of running the enhancement program at current levels for 30 years to be \$420.2 million dollars (present value) of which, \$17.9 million is for fiscal year 1992 (case 3). The most expensive alternative is alternative 4a, in which all enhancement production increases by 15%. This would result in an increase to \$497.4 million over the current \$420.2 m, or an increase in costs of 18.3%. Short of eliminating the entire enhancement program, the greatest cost savings come from elimination of the pink salmon program (case 5).

Under current enhancement levels, the present value of returns to the state from the commercial salmon fishery is estimated to be \$2,423.1 million over 30 years. Looked at from a statewide perspective, two alternatives dominate Table 1. They are the elimination of the entire enhancement program (case 3) and the elimination of the pink salmon enhancement program (case 5). If the entire program was to be eliminated, our estimate is returns to the state of \$2,716.0 m, or an increase over current returns equal to \$293 million in present value, an amount equivalent to an annuity of \$16.3 million per year over returns from current levels. (Recall, however, that there are potentially serious problems with the case 3 simulations.) If the pink salmon program is eliminated, the state would earn a return of \$2,570.4 million in present value over the 30-year

²These data are contained in the full report.

planning horizon. This is a difference of \$147.4 million for the 30 years, or equivalent to an annuity of \$8.2 million per year.

Reviewing only case 5-11 results, cases 5 and 6 discussed above are followed in ranking by the reduction in pink salmon by 15% alternative (case 7b). This alternative is estimated to provide an increase in net benefits of over \$30 million present value over the 30 years. Conversely, an increase in pink salmon enhancement (case 7a), is estimated to decrease net benefits by \$45 million. The only species for which a 15% increase in enhanced production would result in an increase in net benefits over current levels is king salmon. However, the increase is so small that it is most likely statistically insignificant.

Both a 15% decrease in red salmon enhanced production and the elimination of the entire red salmon program would increase net benefits relative to the current level; a 15% increase in red salmon enhanced production would decrease net benefits.

The effects of the different alternatives on the various regions are quite dissimilar. Western Alaska benefits most by elimination of the entire enhancement program, followed by elimination of red salmon enhancement (because it is a major producer of wild red stocks), and elimination of pink salmon. Southeast is a major benefactor of the elimination of the entire program alternative or of the elimination of the pink salmon program alternative. Southeast also benefits by elimination or reduction in red salmon enhancement, but not by as much as the elimination of the pink program. Kodiak also does best by either elimination of the entire program or elimination of the pink program. The worst alternative for Kodiak is elimination of the red salmon enhancement program.

Cook Inlet and Prince William Sound are the only regions that benefit if the planned production levels are met (case 2). Both regions are hurt by the elimination of the pink salmon enhancement program, although Prince William Sound loses more in absolute terms and in percentages than does Cook Inlet (the Cook Inlet decrease is probably statistically insignificant). The elimination of the red salmon program causes benefits to decrease by approximately \$11 million in Prince William Sound. In contrast, elimination of the red program increases net benefits in Cook Inlet. While it is possible that all of the differences in alternatives are statistically indistinguishable from one another for Cook Inlet, this is less likely for Prince William Sound. However, from a statewide perspective, the losses in Prince William Sound due to the worst case scenarios of elimination of either pinks or reds (cases 5 or 6) are more than offset by gains in Western and Southeast Alaska.

Costs and Benefits per Pound

Table 3 compares the statewide cost per pound of production with the statewide average producers' surplus (benefit) per pound. For pink salmon, the cost per pound for an increase of 15% (case 7a) is seven cents per pound. However, the additional producers' surplus is negative seven cents per pound (which means the harvest costs are higher than the revenues attributable to the harvest), for a net loss of 14 cents per pound produced.

Statewide, enhanced red salmon costs an average of 40 cents per pound to produce, but produces only 14 cents per pound in producers' surplus, for a net loss of 26 cents per pound produced.

Chum salmon costs 12 cents per pound on average statewide to produce. It is estimated to produce 10 cents in producers' surplus, resulting in a loss of 2 cents per pound.

On a statewide basis, coho salmon cost an estimated 32 cents per pound to produce. An additional pound of coho salmon is estimated to produce 32 cents of additional producers' surplus, so the net

benefit is zero. However, the statewide average is affected by the costs in Prince William Sound, which do not appear to be plausible estimates of actual costs. Looking at the three regions which produce enhanced coho salmon for which costs are reported, the costs appear to be much higher than the statewide average of 32 cents.

King salmon statewide are estimated to cost 15 cents per pound and produce additional producers' surplus of 86 cents per pound, for a net benefit of 71 cents per pound. However, the statewide average cost per pound is influenced by the costs in Cook Inlet and Prince William Sound, both of which are negative. This reflects the facilities operators' estimates that if king salmon production were increased, then the commercial share would decrease in both percentage and absolute terms. The costs in Southeast Alaska are probably the most accurate. They indicate that an increase in king salmon (case 11a) would cost 84 cents per pound, which is much closer to the statewide average producers' surplus. However, a decrease (case 11b) results in eliminating production that costs only 27 cents per pound. Thus it appears that king salmon production, at least in Southeast Alaska, is approximately at the economically optimal level, although increases may result in benefits greater than the costs.

Discussion of Findings

According to our estimates, the most the enhancement program provides in additional benefits as measured by producers' surplus is \$147 million in present value over 30 years. The enhancement program, however, costs between \$300-500 million in present value over the same time period. However, as mentioned previously, this analysis only considers benefits and cost to the commercial salmon fisheries. Other user groups such as sport and subsistence fishermen were not included. In addition, indirect impacts such as employment and income in fish processing and support services were not included.

None of the alternatives involving increases in enhancement production results in increasing net benefits to any significant degree.³ On the other hand, all of the major reductions in the enhancement program (cases 3, 5, 6, and 4b), as well as smaller reductions for pink salmon (case 7b), resulted in large increases in net benefits.

One significant caveat needs to be mentioned. While it appears that a reduction in enhanced fish would be warranted from an economic point of view, it does not follow that all hatcheries should be forced to shut down. However, *if a region wants to continue with a hatchery program, the most cost effective and marketable production level and composition would result if the program were entirely funded by the local user groups rather than subsidized by the state.* If the fishermen and facilities 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.

If the state reduces or discontinues funding of the enhancement program, 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. To estimate more fully the benefits and costs to other user groups, the state would have to determine the net benefits to those groups.

³Increasing the king salmon enhancement program production by 15% resulted in generation of estimated additional benefits (relative to current) of \$3.4 million over 30 years in present value. It is unlikely that this is statistically significant.

There also may be strategic reasons for maintaining 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 the market in the long run. By maintaining some hatchery production, prices may remain sufficiently depressed to prevent expansion in those areas. However, this is not a strategy which can remain viable over the long run.

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, scaling back the enhancement program, and especially the pink salmon program, would increase net benefits.

Table One: Statewide Summary By Alternative

(Net benefits over 30 years in millions of 1992 dollars, future values discounted at 4%)

ALTERNATIVE	Total Catch (lb)	Total Revenues	Producers' Surplus	Hatchery Costs	Net Benefits
(1) <i>Maintain current hatchery production</i>	23332.47	9491.89	2843.27	420.22	2423.05
(5) <i>Eliminate pink salmon production</i>	19452.47	9404.23	2877.04	306.65	2570.39
(6) <i>Eliminate red salmon production</i>	22817.76	9358.41	2798.53	346.12	2452.41
(7a) <i>Increase pink salmon production by 15%</i>	23904.53	9448.63	2822.03	443.91	2378.12
(7b) <i>Decrease pink salmon production by 15%</i>	22774.95	9520.82	2860.03	403.18	2456.85
(8a) <i>Increase red salmon production by 15%</i>	23404.47	9508.17	2848.71	441.13	2407.57
(8b) <i>Decrease red salmon production by 15%</i>	23260.40	9475.22	2837.49	409.10	2428.38
(9a) <i>Increase chum salmon production by 15%</i>	23615.89	9524.57	2857.48	443.31	2414.18
(9b) <i>Decrease chum salmon production by 15%</i>	23049.04	9455.10	2827.64	414.59	2413.04
(10a) <i>Increase coho salmon production by 15%</i>	23357.68	9502.18	2847.26	426.73	2420.54
(10b) <i>Decrease coho salmon production by 15%</i>	23305.74	9479.51	2838.13	416.40	2421.73
(11a) <i>Increase king salmon production by 15%</i>	23346.81	9505.98	2849.55	423.11	2426.44
(11b) <i>Decrease king salmon production by 15%</i>	23318.08	9477.87	2837.15	417.87	2419.27
(2) <i>Planned hatchery salmon production levels</i>	24071.37	9512.25	2836.38	439.54	2396.84
(3) <i>Eliminate entire salmon hatchery program</i>	16802.32	9101.87	2733.88	17.93	2715.95
(4a) <i>Increase entire hatchery production by 15%</i>	24301.03	9419.07	2816.32	497.38	2318.99
(4b) <i>Decrease entire hatchery production by 15%</i>	22809.22	9488.97	2834.92	380.29	2454.63

Table Two: Regional Net Benefits by Enhancement Alternative

(present value in millions of 1992 dollars, future values discounted at 4% discount rate)

ALTERNATIVE	WESTRN ALASKA	COOK INLET	KODIAK	PRINCE WM SD	SOUTH EAST	STATE TOTAL
(1) <i>Maintain current hatchery production</i>	993.40	276.55	288.69	126.63	737.78	2423.05
(5) <i>Eliminate pink salmon production</i>	1016.91	271.01	312.64	95.02	874.81	2570.39
(6) <i>Eliminate red salmon production</i>	1036.43	284.07	258.72	119.11	754.07	2452.41
(7a) <i>Increase pink salmon production by 15%</i>	990.19	277.31	281.15	116.59	712.88	2378.12
(7b) <i>Decrease pink salmon production by 15%</i>	996.61	276.73	293.54	131.11	758.86	2456.85
(8a) <i>Increase red salmon production by 15%</i>	987.77	276.36	292.62	126.74	724.09	2407.57
(8b) <i>Decrease red salmon production by 15%</i>	999.17	277.54	284.79	126.65	740.23	2428.38
(9a) <i>Increase chum salmon production by 15%</i>	992.53	276.15	286.22	123.13	736.14	2414.18
(9b) <i>Decrease chum salmon production by 15%</i>	994.43	276.92	289.33	126.07	726.29	2413.04
(10a) <i>Increase coho salmon production by 15%</i>	991.88	275.69	288.26	130.46	734.24	2420.54
(10b) <i>Decrease coho salmon production by 15%</i>	994.02	276.82	289.03	126.11	735.76	2421.73
(11a) <i>Increase king salmon production by 15%</i>	992.97	277.32	288.49	130.77	736.89	2426.44
(11b) <i>Decrease king salmon production by 15%</i>	993.94	276.81	288.90	126.69	732.94	2419.27
(2) <i>Planned hatchery salmon production levels</i>	955.09	296.22	274.52	157.15	713.85	2396.84
(3) <i>Eliminate entire salmon hatchery program</i>	1109.59	288.91	309.48	144.29	863.69	2715.95
(4a) <i>Increase entire hatchery production by 15%</i>	978.03	274.76	277.56	114.16	674.43	2318.94
(4b) <i>Decrease entire hatchery production by 15%</i>	1005.97	278.71	288.60	145.08	736.28	2454.63

Table Three: Enhancement Cost and Benefits per Pound

ALTERNATIVE	Enhancement Cost (\$/lb)	Producers' surplus (\$/lb)
(7a) <i>Increase pink salmon production by 15%</i>	0.07	-0.07
(7b) <i>Decrease pink salmon production by 15%</i>	0.05	-0.05
(8a) <i>Increase red salmon production by 15%</i>	0.40	0.14
(8b) <i>Decrease red salmon production by 15%</i>	0.26	0.15
(9a) <i>Increase chum salmon production by 15%</i>	0.12	0.10
(9b) <i>Decrease chum salmon production by 15%</i>	0.03	0.10
(10a) <i>Increase coho salmon production by 15%</i>	0.32	0.32
(10b) <i>Decrease coho salmon production by 15%</i>	0.24	0.36
(11a) <i>Increase king salmon production by 15%</i>	0.15	0.86
(11b) <i>Decrease king salmon production by 15%</i>	0.27	0.83

I. INTRODUCTION

When the enhancement program in Alaska was initiated in the early 1970s, Pacific salmon dominated world salmon markets. Since then, there has been a rapid rise in the supply of salmon worldwide. In Alaska, this has been in large part due to production from the enhancement program, in which the state has invested considerable funds, combined with significant increases in wild stock harvest. The worldwide increase in production is primarily the result of large increases in farmed-salmon production. It appears that supplies of salmon on the world market are more likely to continue to increase than to decrease.

Given this backdrop, the Alaska Legislature's Senate Special Committee on Domestic and International Commercial Fisheries contracted for a benefit-cost analysis as part of its review of the enhancement program. Concerns have also been raised regarding the differential regional impacts of the program. This report summarizes the findings of the study. The results of this analysis are intended to assist policy makers in their deliberations regarding the level of continued state support of the program. The study should also be useful to regional aquaculture associations in planning future enhancement activities.

It should be noted that this study follows traditional methods for benefit-cost analyses, and focuses on the direct benefits and costs to the commercial salmon fishing sector. Benefits and costs to other user groups, such as sport fishermen, the growing charter boat industry, and subsistence fishermen were not included. In addition, indirect impacts, such as employment and income from fish processing, were not included. In order to ultimately draw conclusions and make policy concerning the future of the salmon enhancement program, all of these additional factors must be considered.

Many of the variables upon which these models have been built are difficult to predict and must be continually updated and verified. The models have been provided to the Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, & Development (FRED) for future analyses.

This report is divided into four main sections. The first section describes the scope, objectives, methods, and assumptions of the research and technical limitations of the modeling. The second section, entitled "Results," describes the individual research components (population, demand, fishing costs, and hatchery costs) and the combined results of the research. Section three, entitled "Further Analysis," discusses the costs and benefits per pound of enhanced salmon stocks, sensitivity analysis, and the effect of discount rates on research results. Section four contains further discussion and conclusions of the research.

Scope of the Research

This analysis uses a state accounting stance, which means that, as far as possible, only the benefits and costs occurring in Alaska are considered. Thus, for example, the benefits to consumers in other parts of the U.S. or in other world markets were not considered. This does not imply that these benefits do not exist, but recognizes that they are not captured by the state of Alaska.⁴

⁴The term Alaska and state of Alaska are used broadly to reflect the public of Alaska and not just the state government.

In addition, the analysis makes no attempt to discern whether fishermen benefiting from the enhancement program are residents or nonresidents. To the extent that benefits accrue to nonresidents, the benefits will "flow" out-of-state.

Also, as is standard methodology of benefit cost analysis, this analysis only considers direct benefits and costs. Indirect impacts such as fish processing and service sector support employment and income are not considered, as noted above.

At the direction of the Alaska Legislature due to limited funding, the analysis we conducted concentrates only on Alaska's commercial salmon fisheries. As mentioned above, benefits and costs from subsistence and sport production were not counted. We also did not include the hatchery costs associated with these uses. The analysis also looks at the entire Alaska enhancement program rather than at individual hatcheries or facilities. Therefore, the results apply to the entire state and private program but may not apply to individual facilities.

Research objectives

The request for proposals outlined 17 alternatives to consider. These are given in Table 1.

Table 1: The Alternatives Considered in the Policy Analysis

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

For each alternative, we report the 30-year projections for catch, revenues, producers' surplus, hatchery costs, and net benefits. All dollar figures are expressed in 1992 dollars. We discount

future values at 4% discount rate.⁵ For each alternative, we report projections for 1) Western Alaska (Bristol Bay, the Aleutian islands, and AYK, which is the part of the state with little or no enhancement program), 2) Cook Inlet, 3) Kodiak, 4) Prince William Sound, and 5) Southeast Alaska. We also report state totals.

We also conduct sensitivity analysis by considering changes in exogenous variables on the price and revenue predictions. In addition, we consider the effect of our selection of a discount rate. We also conduct a simple analysis of the costs and benefits produced per pound of enhanced salmon for each of the five species of salmon. The data reported in the Tables are aggregated across gear types in each region. In the actual simulations, *fleet* specific estimates of returns and costs were calculated. However, these data are too voluminous to be included in the report.

The revenue data in each table represents the projected *gross* returns to the region or to the state from the salmon fishery. The cost to fishermen is the value of the most valuable activity they give up to go fishing. We estimated the costs to the fishermen as the minimum level of returns required before the fishermen would participate. Since they would have earned returns equal to the value of their next best alternative if they had not been active in a particular fishery, these costs are real economic costs.⁶ The *producers' surplus* is the difference between the estimated revenues and fishing costs. The producers' surplus measures the net benefits to fishermen.

The cost of providing these net benefits to the fishermen is the cost of the enhancement program. To estimate the net benefits to the entire enhancement program, we subtracted the enhancement costs from the producers' surplus. Alaska Department of Fish and Game fisheries management, administrative, and support costs were included in enhancement program costs and provided by the Divisions of Commercial Fisheries and Fisheries Rehabilitation, Enhancement and Development (FRED).

Research Methods

The research consisted of five parts:

- SALMON POPULATION AND EXPLOITATION MODEL: estimated the quantity of harvestable fish given enhancement production levels,
- INTERNATIONAL SALMON DEMAND MODEL: estimated prices and revenues given the biological model's projections of harvestable fish and assumptions about worldwide production and demand changes,
- COMMERCIAL SALMON FISHING COST MODEL: estimated the net returns to fishermen given the quantity and revenues attainable from the catchable fish,

⁵We examined the cases of four and seven percent "real" discount rates (i.e., we removed the inflation part of the interest rate). Only the 4% discount rate figures are used in the analysis. The 7% discount figures change in magnitude, but do not alter the relative rankings. This is because the costs and benefits of each alternative are relatively evenly distributed over the planning horizon.

⁶It 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.

- **SALMON ENHANCEMENT COSTS:** used hatchery operators' estimates of the costs to produce the enhanced production levels, and
- **SALMON ENHANCEMENT SIMULATION MODEL:** summarized the effects of each of the previous four models.

The models were used to generate projections for 30-year planning horizons. The first three models (biological, demand, and fishing cost) are described in detail in a series of additional reports. For each management alternative, biological stock projections were generated. Collie (1992) developed the population estimates for Prince William Sound pink salmon, Cook Inlet red salmon, Kodiak red and pink salmon, and Southeast king salmon. Other enhanced production estimates were developed by facility operators and by the Alaska Department of Fish and Game. These biological projections were then used in an international salmon demand model to make projections about the prices for each salmon species in each Alaska region (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 cited reports and are appendices A, B, and C, respectively to this summary report. (These reports and associated output data are available from the Legislative Reference Library in Juneau, Alaska.)

Benefits were measured primarily by two variables. First, we were interested in the net benefits to fishermen from the salmon enhancement program. That is, we wanted to estimate the return above fishermen's costs. These net benefits were estimated under different assumptions regarding salmon enhancement production output levels. Second, the cost of producing these benefits to the fishermen is the cost of running the enhancement program. These costs include enhancement facility costs, as well as Department of Fish and Game administrative support and management costs.

The hatcheries were surveyed to determine their current actual costs and their expected costs if enhancement production was increased or decreased. While there is some difficulty in interpreting these numbers in certain instances, measurement of the costs of the enhancement program are relatively straightforward.

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

The net benefits to the state of the enhancement program is the net benefits to the fishermen, as measured by producers' surplus, minus the enhancement costs. This measure indicates the net benefits to fishermen above the costs of providing these benefits.

The request for proposals required that we consider a number of alternative production levels for the enhancement program. These alternatives are described in Table 1. Each production level was to be evaluated over a 15- and a 30-year planning horizon. It is impossible to precisely predict events 15 or 30 years in advance based on less than 15 years of data from an industry that is in transition. However, worldwide trends in demand and supply, suggested by events over the past several decades, give a rough idea of the direction the fishery is heading. While our estimates are likely to be very inaccurate within particular years, they should, on average, capture the trend. Since we were asked to conduct a cost-benefit analysis of the enhancement program over a 30-year lifetime, the trend will be more important than specific yearly predictions.

Modeling Assumptions

All modeling efforts used to project future values require assumptions regarding exogenous variables. The complicated nature of this study required numerous modeling assumptions regarding events in the future. This section summarizes some of the most significant assumptions of the population, demand and fishing cost models. For a more detailed discussion of modeling assumptions, see the individual reports.

The reliability of the results of this analysis depend on the extent to which 1) future international salmon markets reflect current markets, 2) assumptions regarding the future values of exogenous variables are accurate (an exogenous variable is a variable we have no control over such as Norwegian farmed-salmon production and exchange rates), and 3) the model structure is accurate.

Salmon Population and Exploitation Model. It was assumed that the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries would continue to utilize current 1) wild stock escapement targets and 2) fisheries management practices. In addition, it was assumed that all stocks available for harvest by common property fisheries and cost recovery fisheries were harvested. The model estimates of the marine survival of hatchery salmon were obtained from tagging studies conducted by ADF&G biologists.

International Salmon Demand Model. The demand model explicitly characterizes some of the trends in exogenous variables and incorporates dynamic interactions through the effects of lagged quantities and prices. Because of this, the model's salmon price projections are accurate only so long as relative *trends* in international salmon markets remain unchanged. However, Alaska fishermen, processors, and enhanced salmon producers are actively attempting to recapture Alaska's salmon markets. Therefore, to the extent to which these efforts are successful, the research results will underestimate potential net benefits to Alaska. Conversely, if the erosion of Alaska's share of world salmon markets continues at the same rate as it has during the last decade, the research results will overestimate potential net benefits to Alaska.

This modeling effort required a considerable number of assumptions. Some of the most significant assumptions are provided below.

Future values of the following variables were estimated using ordinary-least-squares on the basis of observed 1983 to 1991 growth rates---

- population of the EEC, 0.32% annual growth rate;
- population of Japan, 0.43% annual growth rate;
- population of the United States, 0.92% annual growth rate;
- the "real" food consumption expenditure in Japan, 0.29%; and
- the "real" private consumption expenditure in EEC, 2.9%.

Future values of the next variables, as well as consumer price indexes and tariffs, are held constant at 1992 levels:

- European Currency Unit (ECU)/U.S. exchange rate, 0.7968;
- Norwegian kroner/U.S. dollar exchange rate, 6.3549;
- Japanese yen/U.S. dollar exchange rate, 129.50;
- Norwegian kroner/Japanese yen exchange rate, 0.0491; and
- Norwegian kroner/ECU exchange rate, 7.9755.

Future values for these variable are based on expert opinion---

- The "real" United States personal disposable income, 3.0% annually.
- The total supply of Norwegian farmed Atlantic salmon was held at its 1991 level. This is consistent with the opinion of many experts that growth has reached its maximum sustainable level. However, there are some current indications that the industry may expand in the future, especially with a recent court decision regarding U.S. tariffs on Norwegian imports of farmed salmon.
- Farmed salmon production in Canada and Chile was allowed to grow at 3% annually despite much higher rates of growth in recent years.
- No Russian production was included in the analysis.

Therefore, we believe the background levels of farmed-salmon production are quite conservative. To the extent to which world farmed-salmon production exceeds these estimates, Alaska net benefits will be overestimated, and vice versa.

All wild salmon harvests for Canada, Washington, Oregon, and California were estimated based on 10-year historical averages. All Alaska non-hatchery wild salmon harvests were estimated on the same basis, with the exception of Prince William Sound pink salmon, Cook Inlet red salmon, Kodiak red and pink salmon, and Southeast Alaska king salmon. Wild and enhanced harvests for these salmon species were predicted by Dr. Jeremy Collie in the population modeling portion of this analysis. Some argue that the ten-year average for Alaska wild salmon stocks is too high and others argue that it is too low. If wild harvests are overestimated, resulting net benefits will be underestimated, and vice versa.

Fishing Cost Model. The primary assumptions of the fishing cost model are 1) that future harvests are distributed similarly to 1990 harvests, 2) that fishing and management patterns remain similar, 3) that the numbers of permit-holders remain near 1990 levels, 4) that fishing costs of particular gear types are similar between regions, and 5) that no dramatic changes in ex-vessel prices occur that would significantly alter participation rates.

As a result of the uncertainty regarding actual values of exogenous variables, sensitivity analysis was conducted to simulate high-, mid- and low-salmon-price scenarios. Study results are presented using each of these price scenarios to show the extent of variations in benefits possible as a result of actual price outcomes.

Technical Limitations of the Models

Before we explore the actual findings, let us explain why we believe our estimates must be treated with caution.

- **These predictions are based on models using data from only a small number of years.**

The demand model is based on quarterly data from 1982 to 1991. The fishing cost model is based entirely on data for 1990. To extrapolate 15 or 30 years based on these short time series is dangerous. Certainly projections made in the 1960s could not have foreseen the changes that occurred in the following 20 years.

- **All of our analysis is based on point estimates.**

Even though we predict high, mid, 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 producers' surplus are missing confidence levels which would probably make some of the differences between alternatives insignificant.

- **The production levels under each of the elimination alternatives are vastly different than 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 (Table 1). It is less true for case 6 because enhancement production of red salmon is small relative to the total quantity of red salmon. However, it 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.⁷

- **There are no empirical estimates of cross-price effects between species within aggregate groupings of high and low valued species.**

It was necessary to aggregate Pacific salmon into high-valued (red, king, and coho) and low-valued salmon (chum and pink) in the demand side of the model. This was needed 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 (25%) of the strength imposed in the model, and vice versa. The

⁷This 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 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.

assumed cross-price effects were kept fairly low in order to error on the side of conservatism.⁸ Similar assumptions were made for cross-price effects between species in the high-valued species aggregation. We do have empirical cross-price effects for effects of 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 (Herrmann and Greenberg, 1992).

As a result of species aggregation in the demand model, it was not possible to use the ad hoc cross-price effects between species within a particular grouping when there were simultaneous enhancement production changes to salmon species within the aggregate groupings. For example, if coho and king salmon production were simultaneously increased or decreased, a portion of the resulting change in coho prices would be from the change in coho production (own-price effect), but another portion would be from the change in king production (cross-price effect). In this case, an increase in king production would be likely to lead to lower coho prices. While the own- and cross-price effects are probably different in reality, the model, as estimated implicitly assumes they are the same.

As a result, an accurate estimation of cases 2-4, where there were simultaneous changes in enhancement production, was not possible. Because the model imposed cross-price effect within the groupings may be overstated, the revenues assigned to cases 2, 3, and 4a may be understated, and the revenues for 4b may be overstated. For this reason, only cases 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, 3, and 4a should be viewed as worst cases scenarios, and 4b as a best case scenario. The results from each of these alternatives should be viewed with caution. Because we have less confidence in cases 2-4, these results have been segregated from the main body of the report and from the summary tables.

There are also limitations to the fishing cost model. In particular, we used a novel, previously unused approach to the extremely difficult task of modeling commercial fishing costs. These limitations are discussed below.

- The estimated producers' surplus is "surplus above variable opportunity costs." The variable opportunity costs do not include fixed costs such as vessel and license costs.

The cost model is based on fishing participation. Since costs such as loan payments on vessels and licenses do not vary with participation, these costs are not calculated in the estimated costs. Instead, variable costs, including alternative fishing or employment options are measured. Thus the estimates should be capturing "surplus above variable opportunity costs." Producers' surplus in essence measures the "skill rents" to fishermen. Since fishermen differ, the minimum amount of revenues per fishermen that are required before a particular fisherman decides that it is profitable to participate in an opening will also differ. While this measure can be used to evaluate the changes in costs of harvesting changes in enhanced salmon production, the producers' surplus is based on underestimates of the true, long term fishing costs.

⁸We 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 is an issue which deserves more research.

- **The fishing cost model assumes that revenues affect the number of fishermen, but that the number of fishermen does not affect revenues.**

For the fishing costs, we estimated a model predicting the number of fishermen participating in a particular opening as a function of 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 estimated 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 of openings with different numbers of fishermen, we obtained an estimate of fishing costs as a function of the number of participants.

If our assumption that total revenues are unaffected by the number of fishermen participating is violated, our estimation procedure would be inappropriate. We used ordinary-least-squares to estimate the participation equation (the number of fishermen as a function of total revenues). The marginal cost equation was derived from the participation equation algebraically. The use of ordinary-least-squares would have been inappropriate if the total revenues had also depended upon the number of fishermen since there would have existed a "simultaneous equation bias." However, because we had no independent observations on the stock of fish present, there existed no means of testing this hypothesis. However, we believe that the strength and magnitude of the relationship between effort and total revenues is indicative of the validity of our approach.

- **Simulations of the fishing costs for future years assumed that the season returns behaved as an inflation or a contraction of the returns in 1990.**

In the extrapolation of the fishing cost model to future years, we took the 1990 run for the fishery as our guide to how the run would be dispersed over time and across the statistical areas within the fishery. If a 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 with 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 cost equation 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. Producers' surplus was estimated as the difference between the fishing cost estimates and the revenue estimates.

- **Fisheries for which fishing costs were not explicitly estimated used fishing costs based on the average fishing costs for fisheries with similar fleets.**

One problem with our fishing cost model, which is consistent across all of the analyses of alternatives, is the problem of extrapolating cost data from one fishery to another. In particular, fishing costs were estimated 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. This

problem is particularly 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 producers' surplus in Western Alaska may be very inaccurate. However, the evidence from the other drift net fleets suggests that the drift net fleets are very similar. Producers' surplus was estimated to be around 14-15% of total revenues in each fleet. The estimated standard error of that estimate was $\pm 3\%$. The problem is simply that the extrapolation is for a fleet of more than double the size of the fleets for which explicit parameter estimates exist. One clue as to the direction of this error is in our estimates of the number participating for those fleets for which we have data. The estimates of the number of vessel days for the season are always less than the actual number.⁹ This means that our estimate of costs for the marginal fishermen may be overstated, understating the producers' surplus. This will tend to dampen the effect of alternatives that are favorable to the Western Alaska fleets such as cases 3, 5, and 6.

- The simulation estimates for the final 15 years of the 30-year planning horizon are the simple averages of the 10th through 15th years.

Our estimates of catch, revenues, and producers' surplus for the second 15 years of the planning horizon are based on the average of years 10 to 15 (2001-2006). However, the cost estimates from the hatcheries were provided by the hatcheries for the entire 30-year period. We 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 15th year were quite a bit higher than previous years. We believed this to be due to the way errors become magnified the further out one predicts in a dynamic model. The model's ability to project beyond a ten-year horizon is limited given the relatively short time-series data available for estimating the model. Therefore, we used the years 10-15 average instead. We believe this is a better estimate of potential net benefits and has no effect on the relative rankings of the alternatives.

- Hatchery costs associated with production of species caught by sport and subsistence users was not considered in the analysis.

The analysis we were requested to undertake was only for the commercial fisheries. Therefore, enhancement costs associated with fish stocks used by other user groups were not considered. However, neither were the benefits to these groups considered. This is work which deserves further attention, but is beyond the scope of this study.

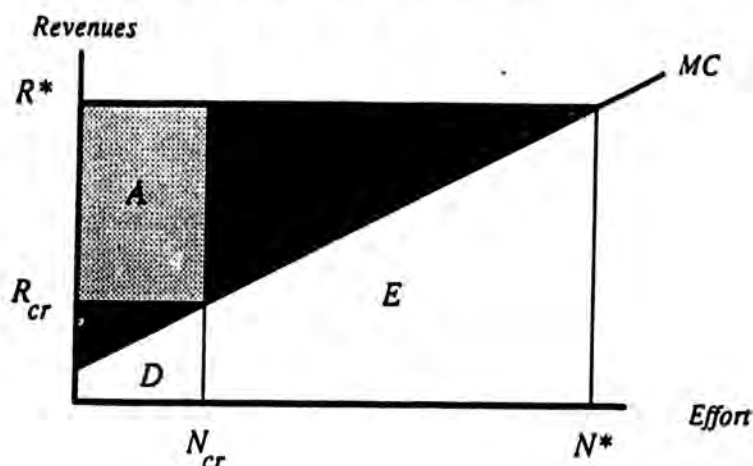
- Enhancement costs associated with "cost recovery" are revenues to the fishermen catching those fish, and are not included in social costs.

The direct costs of the enhancement program are the costs of the fish produced. To recover these costs, the hatcheries are empowered to offer contracts to fishermen to catch fish for the hatchery. These fish are then sold on the market and the profits are used to cover the costs of the hatchery raised fish. To the operators of hatcheries, the costs associated with the cost recovery are reported as accounting costs. However, these costs are revenues to the fishermen who contract to do the cost recovery catch. Since these fishermen face similar opportunity costs as the fishermen in the common property commercial fishery, we used the estimate of variable fishing costs from the common property fleets to determine what portion of the cost recovery costs are social costs and what part are social benefits.

⁹In part, this comes from using a double-log model to estimate participation, and then converting the parameter estimates to a linear model to predict costs.

The concepts can be most readily seen in Figure One. Figure One represents a stylized version of how the total revenues of the fishery are divided up between commercial fishermen and the hatchery operators. On the vertical axis is represented the value of the fish a single fisherman can catch and the cost of participating for each fisherman. On the horizontal axis, the fishermen are indexed from left to right as the most efficient (lowest opportunity costs) to least efficient (highest opportunity costs). The upwards sloping line labeled "MC" represents the opportunity cost of each additional fisherman.

Figure One: Net benefits calculation



Given that total revenues are such that an individual fisherman may earn revenues of R^* , there will be N^* fishermen who participate in the fishery. Thus, total revenues is the area of the box with height R^* and width N^* , which has value R^*N^* . The total fishing costs associated with earning revenues R^*N^* is the area under the opportunity cost function, MC, represented by the areas labeled D and E. The area above the MC line (areas A, B, and C) represents producers' surplus. Total hatchery costs are the areas A, B, and D. Areas B and D represent the cost recovery costs. The area A represents the profits the hatchery makes on the cost recovery, but these profits are used to pay for the hatchery costs. The cost recovery costs B and D are costs to the hatchery, but revenues to the N_{cr} fishermen who participate in the cost recovery. The area D represents the costs to the N_{cr} fishermen participating in the cost recovery, B is their producers' surplus. Thus, the net benefits to fishermen after hatchery costs are accounted for is areas B and C. Area A is producers' surplus that is captured by the hatcheries, but goes to paying for the enhancement costs.

II. RESULTS

We now turn to the results of our analysis. The data presented in this section was developed using the computer models and the assumptions outlined in the previous section. The biological, population and exploitation numbers were developed by Dr. Jeremy Collie and by the facilities operators. The revenues numbers were developed by Drs. Mark Herrmann and Joshua Greenberg. The fishing cost and producers' surplus numbers were developed by Dr. John Boyce, and the enhancement cost numbers were from a survey conducted by the Alaska State Legislature

and Alaska Department of Fish and Game (FRED Division) and analyzed by Drs. John Boyce and Diane Bischak.

Although all of the limitations discussed in the previous section apply, the most important limitation of our analysis is our inability (which was due mainly to time limitations) to develop distributions and hence confidence intervals for our estimates. We have already indicated, and emphasize again, that our confidence in cases 2-4 is much lower than for the remaining cases. All of the estimates presented in this section are based on point estimates of very complex analyses. Therefore, we cannot gauge the statistical significance of differences between the results for different alternatives. Our analysis is thus based on differences in our mean estimates between alternatives.

Table 2: Total Commercial Catch by Enhancement Alternative

(millions of pounds, 30 year sum)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
1	7835.77	1702.43	2425.80	5215.02	6153.45	23332.47
2	7835.79	1840.07	2424.90	5702.03	6268.58	24071.37
3	7835.24	1259.05	1808.76	1548.73	4350.53	16802.32
4a	7835.85	1770.10	2517.54	5754.06	6423.49	24301.03
4b	7835.69	1635.65	2336.98	5117.45	5883.45	22809.22
5	7835.77	1362.23	2135.11	2199.21	5920.16	19452.47
6	7835.77	1604.31	2266.73	4988.08	6122.87	22817.76
7a	7835.77	1753.46	2470.38	5656.48	6188.45	23904.53
7b	7835.77	1651.40	2385.11	4784.22	6118.46	22774.95
8a	7835.77	1718.31	2447.88	5244.94	6157.58	23404.47
8b	7835.77	1687.44	2402.77	5185.11	6149.32	23260.40
9a	7835.81	1702.43	2450.56	5273.15	6353.95	23615.89
9b	7835.73	1702.43	2401.04	5156.89	5952.96	23049.04
10a	7834.25	1703.06	2426.13	5222.87	6171.38	23357.68
10b	7835.77	1701.79	2425.47	5207.18	6135.53	23305.74
11a	7835.81	1702.55	2425.80	5216.71	6165.94	23346.81
11b	7835.73	1702.29	2425.80	5213.27	6140.99	23318.08

Differences in Catch among the Alternatives

The first step was to predict population exploitation levels. This analysis is discussed in more detail in Collie (1992). The results, by alternative, are contained in Table 2 above, which shows millions of pounds of fish by region for all salmon species summed over the 30-year planning horizon. The data include estimates of wild as well as enhanced stocks. The differences in the sums over the alternatives represents the net difference in total salmon production given the various enhancement levels.

The enhancement program effect on catch is quite large. Under current hatchery production (case 1), output over the next 30 years is projected to be 23,333 million (m.) pounds, or 778 million pounds per year. If the entire hatchery program were to be eliminated (case 3), output would drop to 16,802 million pounds over the 30-year planning horizon, or to 560 million pounds per year. The hatchery program is thus responsible for approximately 28% of Alaskan salmon production. However, a 15% increase in all hatchery production does not cause a proportional increase in harvested fish. Comparison of case 4a with case 1 shows that a 15% increase in total hatchery production causes an increase of 3.2% in total fish caught, which is lower than a proportional 15% increase would be (4.2%). This is because of foraging competition between wild and enhanced stocks and because of mixing problems in harvesting.

Cases 5 and 6 show that the pink salmon enhancement program is considerably larger than the red salmon program, so an elimination of the entire pink salmon program would have a larger effect (16.6% less than current) than elimination of the red salmon program (2.2% less than current). The other species are even less important in terms of total output.

There are also regional differences in production levels of the enhancement program. Western Alaska produces only minute amounts of king, coho, and chum salmon. There are no enhanced pinks or reds produced in Western Alaska. Cook Inlet has approximately 20% of its production from enhanced pink salmon, with an additional 6% of its production from enhanced red salmon. Cook Inlet also produces small amounts of king, coho, and chum salmon. Kodiak has about 12% of its current production from enhanced pink salmon, and an additional 7% from enhanced red salmon. Kodiak also produces smaller amounts of each of the other species. Prince William Sound has about 42% of its total catch from enhanced pink salmon. An additional 4% of the current total catch comes from enhanced red salmon, and an additional 7.5% from enhanced chum salmon.¹⁰ Small amounts of king and coho are also produced in Prince William Sound. Southeast receives 3.7% of its current production from enhanced chum salmon, about 3.8% from enhanced pink salmon, about 1.4% from enhanced king salmon, about 2% from enhanced coho salmon, and about 0.5% from enhance red salmon. Thus, of all of the regions, Prince William Sound is most dependent upon enhancement for its current production levels. Western Alaska is the least dependent.

Differences in total revenues among the alternatives

Proportional increases in catch do not imply proportional increases in gross revenues. (It should be noted that this section discusses gross revenues, and not net benefits, of enhanced production.)

¹⁰This estimate is made by extrapolating proportionately from the 15% reduction in chum salmon (case 9a) from the current level production. This method of extrapolation is used below for species other than pink and red salmon. For those species, the percentages in the text are derived from the difference in production over 30 years in case 1 (current production levels are maintained) and the elimination of pink (case 5) and elimination of red (case 6) enhancement programs, respectively.

Revenues depend upon both quantities and prices. Since increases in quantities cause prices to decrease, revenues may either increase or decrease as quantities decrease. A much more thorough discussion of the revenue effects is contained in the discussion of the demand model (Herrmann and Greenberg, 1992). However, a summary of the revenue differences between the alternatives is contained in Table Three. Cases 2-4 have been separated from the rest to emphasize that these estimates are less accurate than those for cases 1 and 5-11.

Table 3: Gross Revenues by Enhancement Alternative

(present value in millions of 1992 dollars, future values discounted at 4% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
1	4167.79	971.00	859.36	1428.06	2065.68	9491.89
5	4263.68	934.06	901.06	995.61	2309.83	9404.23
6	4354.59	931.62	768.07	1236.60	2067.53	9358.41
7a	4154.82	972.85	849.70	1444.63	2026.62	9448.63
7b	4180.72	968.08	865.61	1403.25	2103.16	9520.82
8a	4143.60	977.08	872.09	1450.22	2065.19	9508.17
8b	4192.13	965.91	845.60	1405.45	2066.13	9475.22
9a	4163.64	969.69	859.74	1431.51	2099.98	9524.57
9b	4171.96	972.31	858.60	1423.79	2028.44	9455.10
10a	4162.83	970.95	859.20	1431.70	2077.50	9502.18
10b	4170.04	971.18	859.63	1424.58	2054.08	9479.51
11a	4165.84	970.72	858.96	1429.03	2081.42	9505.98
11b	4169.87	971.29	859.78	1427.04	2049.88	9477.87
2	4061.99	1034.46	833.69	1533.45	2048.66	9512.25
3	4654.05	925.04	844.00	755.25	1923.53	9101.87
4a	4102.64	972.06	850.27	1446.75	2047.35	9419.07
4b	4220.93	965.21	847.79	1427.09	2027.96	9488.97

We can now see the revenue effect of the enhancement program. Comparing the current levels (case 1) with the elimination of the entire program (case 3), the enhancement program is seen to produce revenues over 30 years worth approximately \$390 million today. This is equivalent to an

annual return (undiscounted) of \$21.7 million.¹¹ However, not every region gains in terms of revenues by the enhancement program. Comparing case 1 with case 3 across regions shows that Western Alaska actually *loses* \$486.3 (\$27.0 million per year) in present value in revenues due to the enhancement program. All other regions, however, gain in revenues by having the enhancement program at its current levels. Cook Inlet gains about \$46 million in present value over 30 years; Kodiak gains about \$15.4 million in revenues, Prince William Sound gains \$672.8 million (about \$37.4 per year) in revenues; and Southeast gains \$142.2 million in revenues. Overall, the gains in gross revenues to the other regions are greater than the losses to Western Alaska.

Under the eliminate pinks alternative (case 5), revenues rise in Western Alaska, Kodiak, and Southeast, but drop in Cook Inlet and Prince William Sound. Overall, the declines in gross revenues (especially for Prince William Sound) exceeds the increases in gross revenues to the other regions. The elimination of red salmon enhancement option also has net negative effects on revenues relative to the current output levels, with only Western Alaska showing gains in revenues.

Considering the 15% increases (cases 7a-11a) and the 15% decreases (cases 7b-11b) in production by species, all species except pink salmon have a positive effect on statewide revenues. That is, except for pink salmon, a 15% increase in enhancement production for the species causes gross revenues to increase, and a 15% decrease causes gross revenues to decrease. A 15% increase in pink salmon causes statewide revenues to decrease (and vice versa). However, the effects on revenues by region are not as clear. In the case of pink salmon (cases 7a and 7b), an increase of 15% helps Cook Inlet and Prince William Sound, but hurts revenues in Western Alaska, Kodiak, and Southeast.

For red salmon (cases 8a and 8b), only Western Alaska has lower revenues as a result of an increase in red salmon enhancement production. All other regions gain in gross revenues with an increase in red salmon, and the net effect on revenues is positive. An increase in chum salmon (case 9a) has a net positive effect on revenues, but hurts Western Alaska and Cook Inlet, while a decrease (case 9b) has the opposite effect. An increase in coho enhancement production (case 10a) also has a net positive effect, but reduces revenues in Western Alaska, Cook Inlet, and Kodiak. King salmon has a similar effect as coho enhancement, with increases in production increasing revenues in Prince William Sound and Southeast, but decreasing revenues elsewhere (case 11a). A decrease in king enhancement production has the opposite effect (case 11b).

For cases 2-4, for which we believe there is reason to suspect the results, we find the following. The planned enhancement production (case 2) is estimated to have a positive effect overall on revenues statewide. However, not all regions gain. Prince William Sound and Cook Inlet, who express plans for the greatest increase in enhancement production (9.3% and 8.1% increases over current output production over 30 years, respectively) show gains in revenues from these plans (a 7.3% and 6.4% increase in present value of gross revenues over 30 years, respectively). Each of the other regions stands to lose revenues as a result of the planned output of all of the regions. Again, we caution the reader in placing too much credence on the magnitudes of changes in revenues.

Cases 4a and 4b emphasize this point well. These are the cases where enhancement output is to increase or decrease by 15% for all species simultaneously. Aside from the fact that it would never make economic sense to follow such a policy unless each species contributed exactly the same marginal return, the results show how the demand model got "confused" by the simultaneity of the changes in enhancement production levels. First, *both* an increase and a decrease of 15% of all

¹¹All of the 30-year present value calculations given in the text may be converted into equivalent annual annuities by dividing the 30-year present value number by 17.9837.

species simultaneously caused statewide revenues to decrease relative to the current output levels. Secondly, the direction of the effects is quite different across regions. Western Alaska appears to respond reasonably, with an increase in enhancement production for all species causing revenues to decline, and a decrease causing revenues to increase. Conversely, both Prince William Sound and Cook Inlet show increases in revenues with an increase in enhancement production and decreases in total revenues with decreases in enhancement production. This is presumably because they are the major producers of enhanced fish. The results are less clear for Kodiak and for Southeast. In each case, these regions end up with a decrease in revenues relative to current enhancement output levels. Thus the aggregate reduction in revenues from these two cases cannot be explained by differential regional effects alone.

Table 4: Producers' Surplus by Enhancement Alternative

(present value in millions of 1992 dollars, future values discounted at 4% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
1	993.40	311.34	317.38	311.80	909.34	2843.27
5	1016.91	295.95	334.69	198.25	1031.25	2877.04
6	1036.43	297.47	277.49	276.32	910.82	2798.53
7a	990.19	312.24	313.05	317.17	889.38	2822.03
7b	996.61	310.04	321.23	303.99	928.16	2860.03
8a	987.77	313.68	322.54	315.66	909.05	2848.71
8b	999.17	309.13	311.99	307.62	909.57	2837.49
9a	992.53	310.95	317.38	312.59	924.04	2857.48
9b	994.43	311.71	317.25	310.69	893.55	2827.64
10a	991.88	311.30	317.29	312.44	914.36	2847.26
10b	994.02	311.31	317.52	311.18	904.11	2838.13
11a	992.97	311.33	317.17	311.92	916.17	2849.55
11b	993.94	311.29	317.58	311.78	902.56	2837.15
2	955.09	332.27	303.21	352.20	893.61	2836.38
3	1109.59	290.69	310.86	150.48	872.27	2733.88
4a	978.03	312.23	313.51	315.58	896.97	2816.32
4b	1005.97	308.19	313.84	313.03	893.89	2834.92

Differences in Producers' Surplus among the Alternatives

When all else is held constant, an increase in revenues is preferred over a decrease in revenues. However, all else is not held constant. Some alternatives which result in more revenues are due to a reduction in catch and a corresponding increase in price. Other alternatives where revenues increase may be due to an increase in catch, with a correspondingly lower price. Clearly, these two cases are not identical in the way fishermen perceive them. If revenues rise because a price increase more than offsets a decrease in catch, then along with the increase in revenues will be a decrease in costs. This is better than an increase in revenues and an increase in costs, due to the increase in catch more than offsetting the corresponding decrease in price.

These examples suggest that a better measure of the welfare of the fishermen is the net benefits to fishermen as measured by producers' surplus. Estimates of producers' surplus by alternative and by region are contained in Table 4 above.

Producers' surplus measures the difference between revenues and fishing costs. It is the net benefits to fishermen. In Figure One, total revenues correspond to the entire box, areas A, B, C, D, and E. However, producers' surplus is the area above the fishing cost line MC, or areas A, B, and C. For the moment, we ignore that part of the producers' surplus (area A) absorbed as enhancement costs.

The data in Table 4 shows that the effects of the different alternatives on fishermen are considerably dampened when producers' surplus is used as the measure rather than total revenues. First of all, the difference in the 30-year present value between the highest (case 5, elimination of pink salmon) and lowest (case 3, elimination of all the hatchery program) producers' surplus values in Table 4 is \$143.2 m, or a difference of an annuity worth about \$8.0 million per year. This is substantially smaller than the \$422.7 million difference in present value between the highest revenue alternative (case 9a) and the lowest (case 3), which is equivalent to an annuity of \$23.5 million per year.

Producers' surplus accounts for approximately 30% of total revenues for most of the alternatives. The directional changes relative to the current enhancement levels alternative (case 1) are generally consistent with the changes in revenues at both the statewide level and for the regions. The one exception at the statewide level is for the planned enhancement levels (case 2). Statewide, revenues are projected to increase relative to the current level if planned enhancement production occurs; however, producers' surplus is estimated to decline. This is due to the magnitude of the changes at the regional levels rather than to the direction of changes at the regional level. Almost all of the decrease in revenues in Southeast from planned production relative to current production is accounted for in the reduction in producers' surplus. This suggests the effect on Southeast of the planned production levels is almost entirely due to a reduction in prices of the species caught in Southeast.

The elimination of the entire program and of the red salmon enhancement program (cases 3 and 6) each cause statewide producers' surplus to decrease. However, the elimination of the pink salmon program (case 5) causes statewide producers' surplus to increase. Producers' surplus in Western Alaska increases if any of the programs are eliminated. In Cook Inlet and Prince William Sound, producers' surplus decreases if any part of the program is eliminated. Producers' surplus in Kodiak increases only if just pink salmon enhancement is eliminated (case 5); Southeast gains if either program is eliminated individually, but loses if both are eliminated (case 3). This effect on Southeast is probably due more to the difficulties associated with case 6 rather than a depiction of what would actually occur.

While a 15% increase (decrease) of chum, coho, or king causes an increase (decrease) in statewide producers' surplus, the magnitude is quite small and not likely to be significant. The effects of

15% increases or decreases in pink and red salmon are more noticeable (though we cannot say whether they are statistically significant). The changes in producers' surplus for pink and red salmon increases and decreases are similar in sign to the effect of changes in revenues. More pink salmon helps Prince William Sound and Cook Inlet, and more red salmon helps those two regions plus Kodiak. Both Western Alaska and Southeast have reductions (increases) in producers' surplus from increases (decreases) of either pink or red salmon.

The cases where production of enhanced fish for all species is increased or decreased simultaneously has even more muddled effects on producers' surplus than it has on revenues. Only in Cook Inlet and Western Alaska are the effects as one might expect. Prince William Sound producers' surplus is estimated to increase (though not by much) under either an increase or a decrease. Producers' surplus in Kodiak and Southeast is estimated to decrease under either alternative, which is consistent with the effect on revenues in those regions.

Table 5: Enhancement Costs by Enhancement Alternative

(present value in millions of 1992 dollars, future values discounted at 4% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
1	0.00	34.80	28.69	185.17	171.56	420.22
5	0.00	24.94	22.05	103.23	156.44	306.65
6	0.00	13.40	18.77	157.20	156.75	346.12
7a	0.00	34.93	31.90	200.59	176.50	443.91
7b	0.00	33.32	27.69	172.88	169.29	403.18
8a	0.00	37.33	29.93	138.92	184.95	441.13
8b	0.00	31.59	27.20	180.97	169.34	409.10
9a	0.00	34.80	31.16	189.46	187.89	443.31
9b	0.00	34.80	27.92	184.62	167.26	414.59
10a	0.00	35.60	29.02	181.98	180.11	426.73
10b	0.00	34.48	28.49	185.08	168.35	416.40
11a	0.00	34.00	28.69	181.14	179.28	423.11
11b	0.00	34.48	28.69	185.09	169.62	417.87
2	0.00	36.05	28.69	195.05	179.75	439.54
3	0.00	1.78	1.38	6.18	8.58	17.93
4a	0.00	37.47	35.95	201.43	222.53	497.38
4b	0.00	29.48	25.24	167.96	157.61	380.29

Enhancement Costs under the Different Alternatives

We have observed that the revenue differences between the alternatives are within \$422.7 million of one another and that the producers' surplus estimates differ by at most by \$143.1 million (both values expressed in terms of a 30-year present value). In this section, we consider the costs of producing the benefits to the fishermen. The enhancement costs we measure correspond to the area *A* in Figure One. As we mentioned above, these enhancement costs do not include cost recovery costs (areas *B* and *D*), which are revenues to the fishermen. These costs are contained in Table 5. They are also expressed in millions of 1992 dollars and as a 30-year present value sum.

We estimate that the costs of running the enhancement program at current levels for 30 years to be \$420.2 million dollars (present value). \$17.9 million of this is for fiscal year 1992 (case 3). The most expensive alternative is alternative 4a, in which all enhancement production increases by 15%. This would result in an increase to \$497.4 million over the current \$420.2 million, or an increase in costs of 18.3%. Short of eliminating the entire enhancement program, the greatest cost savings come from elimination of the pink salmon program (case 5).

Regional differences in the enhancement program are also very clear from Table 5 above. Prince William Sound and Southeast account for almost 85% of the current hatchery costs. Cook Inlet and Kodiak account for the balance, with slightly more spent in Cook Inlet than in Kodiak. Western Alaska has insignificant costs relative to the other regions.¹² The costs in Prince William Sound are less accurate than for the other regions because the facility in Valdez did not report costs for its pink or chum operations. We used Prince William Sound Aquaculture Corporation data to estimate Valdez costs and adjusted costs in proportion to Valdez production levels. All of the costs are aggregates for the region, and may conceal differences across facilities.

All cost data represent facility operators' estimates of costs under the various alternatives. There is reason to believe that the costs may be overstated for a number of the reduction scenarios. For example, the cost savings from elimination of the pink program is \$113.6 million or about a 27% reduction. Cost savings from elimination of the red salmon program result in a reduction of \$74.1 million, or a savings of 18%. Thus, elimination of the two largest programs reduces costs by less than 40% according to the operators. This appears to imply that there are costs which must be incurred whether production of a particular species occurs or not. The only way to eliminate those costs appears to be to close the entire facility. It is likely that faced with such an option, other cost savings would appear.

Net Benefits under the Different Alternatives

We are now ready to assess the net benefits under the various alternatives. The net benefits are derived by subtracting the enhancement costs of Table 5 from the producers' surplus estimates of Table 4. This data is contained in Table 6. Again, all values are expressed in millions of 1992 dollars.

Under current enhancement levels, the present value of returns to the state from the commercial salmon fishery is estimated to be \$2,423.1 million over 30 years. Looked at from a statewide perspective, two alternatives dominate Table 6. They are the elimination of the entire enhancement program alternative (case 3) and the elimination of the pink salmon enhancement program (case 5). If the entire program were to be eliminated, our estimate is a return to the state of \$2,716.0 million, or an increase over current returns equal to \$293 million in present value, or equivalent to an annuity of \$16.3 million per year over returns from current levels. Recall, however, that there are

¹²In fact, Western Alaska costs are not included at all. The one hatchery in Western Alaska did not respond to the hatchery cost survey.

potentially serious problems with the case 3 simulations. If the pink salmon program is eliminated, the state would earn a return of \$2,570.4 million in present value over the 30-year planning horizon. This is a difference of \$147.4 million for the 30 years, or equivalent to an annuity of \$8.2 million.

Table 6: Net Benefits by Enhancement Alternative (4% discount rate)

(present value in millions of 1992 dollars, future values discounted at 4% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
1	993.40	276.55	288.69	126.63	737.78	2423.05
5	1016.91	271.01	312.64	95.02	874.81	2570.39
6	1036.43	284.07	258.72	119.11	754.07	2452.41
7a	990.19	277.31	281.15	116.59	712.88	2378.12
7b	996.61	276.73	293.54	131.11	758.86	2456.85
8a	987.77	276.36	292.62	126.74	724.09	2407.57
8b	999.17	277.54	284.79	126.65	740.23	2428.38
9a	992.53	276.15	286.22	123.13	736.14	2414.18
9b	994.43	276.92	289.33	126.07	726.29	2413.04
10a	991.88	275.69	288.26	130.46	734.24	2420.54
10b	994.02	276.82	289.03	126.11	735.76	2421.73
11a	992.97	277.32	288.49	130.77	736.89	2426.44
11b	993.94	276.81	288.90	126.69	732.94	2419.27
2	955.09	296.22	274.52	157.15	713.85	2396.84
3	1109.59	288.91	309.48	144.29	863.69	2715.95
4a	978.03	274.76	277.56	114.16	674.43	2318.94
4b	1005.97	278.71	288.60	145.08	736.28	2454.63

Reviewing only case 5-11 results, cases 5 and 6 discussed above are followed in ranking by the reduction in pink salmon by 15% alternative (case 7b). This alternative is estimated to provide an increase in net benefits of over \$30 million present value over the 30 years. Conversely, an increase in pink salmon enhancement (case 7a), is estimated to decrease net benefits by \$45 million. The only species for which a 15% increase in enhanced production would result in an increase in net benefits over current levels is king salmon. However, the increase is so small that it is most likely statistically insignificant.

Both a 15% decrease in red salmon enhanced production and the elimination of the entire red salmon program would increase net benefits relative to the current level; a 15% increase in red salmon enhanced production would decrease net benefits.

The effects of the different alternatives on the various regions are also quite dissimilar. Western Alaska benefits most by elimination of the entire enhancement program, followed by elimination of red salmon enhancement (because it is a major producer of wild red stocks), and elimination of pink salmon. Southeast is also a major benefactor of elimination of the entire program or of elimination of the pink salmon program. Southeast also benefits by elimination or reduction in red salmon enhancement, but not by as much as with the elimination of the pink program. Kodiak also does best by either elimination of the entire program or elimination of the pink program. The worst alternative for Kodiak is elimination of the red salmon enhancement program.

Cook Inlet and Prince William Sound are the only regions that benefit if the planned production levels are met (case 2). Both regions are hurt by the elimination of the pink salmon enhancement program, although Prince William Sound loses more in absolute terms and in percentages than does Cook Inlet (the Cook Inlet decrease is probably statistically insignificant). The elimination of the red salmon program causes benefits to decrease by approximately \$11 million in Prince William Sound. In contrast, elimination of the red program increases net benefits in Cook Inlet. While it is possible that all of the differences in alternatives are statistically indistinguishable from one another for Cook Inlet, this is less likely for Prince William Sound. However, the losses in Prince William Sound due to the worst case scenarios of elimination of either pinks or reds (cases 5 or 6) are more than offset by gains in Western Alaska and Southeast Alaska.

III. FURTHER ANALYSIS

The analysis is extended in three directions in this section. First, we consider the costs and benefits of enhancement on a per pound basis. Second, we conduct a sensitivity analysis using point estimates from high and low price estimates. Third, we examine how sensitive our results are to our choice of discount rate.

Per Pound Costs and Benefits of Salmon Enhancement

The cost of producing enhanced salmon stocks was estimated by surveying enhancement facility operators. The survey asked the facility managers their costs for each of the production levels depicted in cases 1-11. In addition, the survey asked for costs if the chum, coho, and king salmon portions of the program were eliminated. The purpose of all of these cases was to determine the marginal and average costs of enhanced fish production.

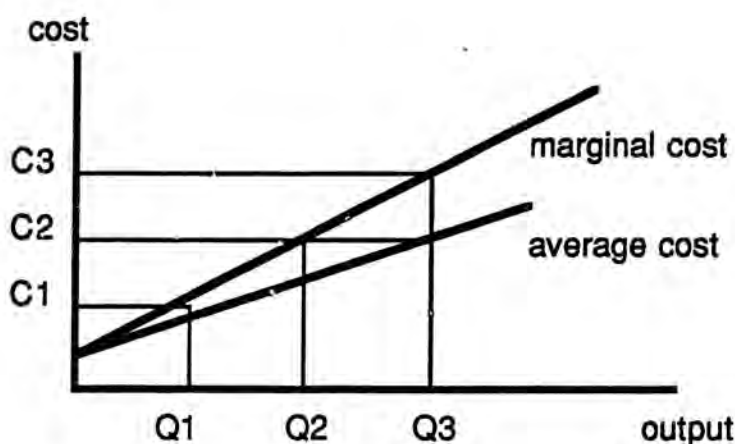
However, it is likely that this survey procedure understated the cost of producing enhanced fish stocks. This point is shown in Figure Two, using three different levels of fish production or output. The marginal cost line measures the cost of an additional unit of output. For example, the cost of the output Q1 is C1. If output were to be increased to Q2, then the cost of the Q2 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.

The analysis of the potential effects of elimination of all or parts of the enhancement program reveals some interesting information about the cost per pound of enhanced fish production. Eliminating the pink salmon program reduces the estimated catch over 30 years by 3.880 billion pounds and reduces enhancement costs by \$ 191.0 million in undiscounted 1992 dollars over the

30-year planning horizon.¹³ Thus, the cost per pound of the pink enhancement program is approximately 5 cents per pound.

A similar comparison can be made for the red salmon program. The estimated cost of producing a hatchery raised red salmon is approximately 16 cents per pound. Therefore, the cost per pound of producing red salmon is about three times the cost of pink salmon production.

Figure Two: Marginal and average hatchery costs



To further examine the hatchery cost per pound of various species, we analyzed data from cases 7 through 11. The statewide averages are weighted averages, where the weights are proportional to a region's share in the quantity of enhanced stocks for each species. The results are presented in the following Table 7. The results are consistent for all species except king salmon, in that the statewide average cost per pound of an increase in production exceeds the cost per pound of a decrease by the same magnitude.

The reason that there are negative numbers in some of the regions is that some facilities reported a decrease in commercial costs if a particular species was enhanced. This was not because total costs declined, but because the commercial share of the increased harvest declined sufficiently to cause commercial costs to decline. This means that the production change would have been accompanied by allocation changes between user groups.

The final column of Table 7 compares the statewide cost per pound of production with the statewide average producers' surplus (benefit) per pound. For pink salmon, the cost per pound for an increase of 15% (case 7a) is seven cents per pound. However, the additional producers' surplus is -seven cents per pound, for a net loss of 14 cents per pound produced.

Statewide, enhanced red salmon costs an average of 40 cents per pound to produce, but produces only 14 cents per pound in producers' surplus, for a net loss of 26 cents per pound produced.

Chum salmon costs 12 cents per pound on average statewide to produce. It is estimated to produce ten cents in producers' surplus, resulting in a two cent loss per pound.

¹³The cost per pound is the average cost per pound over the entire planning horizon. Therefore, undiscounted 1992 dollars are the appropriate measure for evaluating cost per pound.

Table 7: Costs and Benefits per Pound of Enhanced Salmon (\$/lb)

Species	Case	Cook Inlet	Kodiak	Prince William Sound	South-east	State Average Cost/lb	State Average PS/lb
pink	5	0.05	0.04	0.05	0.11	0.05	-0.02
	7a	0.01	0.12	0.06	0.22	0.07	-0.07
	7b	0.05	0.04	0.05	0.11	0.05	-0.05
red	6	0.36	0.11	0.21	0.78	0.24	0.16
	8a	0.27	0.09	0.20	3.98	0.40	0.14
	8b	0.36	0.11	0.24	0.87	0.26	0.15
chum	9a	0.000	0.17	0.12	0.11	0.12	0.10
	9b	0.000	0.06	0.02	0.04	0.03	0.10
coho	10a	2.13	1.70	-0.74	0.67	0.32	0.32
	10b	0.81	1.03	0.02	0.30	0.24	0.36
king	11a	-11.08	0.00	-4.18	0.84	0.15	0.86
	11b	3.79	0.00	0.08	0.26	0.27	0.83

On a statewide basis, coho salmon cost an estimated 32 cents per pound to produce. An additional pound of coho salmon is estimated to produce 32 cents of additional producers' surplus, so the net benefit is zero. However, the statewide average is affected by the costs in Prince William Sound, which do not appear to be plausible estimates of actual costs. Looking at the three regions which produce enhanced coho salmon for which costs are reported, the costs appear to be much higher than the statewide average of 32 cents.

King salmon statewide are estimated to cost 15 cents per pound and produce additional producers' surplus of 86 cents per pound, for a net benefit of 71 cents per pound. However, the statewide average cost per pound is influenced by the costs in Cook Inlet and Prince William Sound, both of which are negative. This reflects the facilities operators' estimates that if king salmon production was increased, then the commercial share would decrease in both percentage and absolute terms. The costs in Southeast Alaska are probably the most accurate. They indicate that an increase in king salmon (case 11a) would cost 84 cents per pound, which is much closer to the statewide average producers' surplus. However, a decrease (case 11b) results in eliminating production that costs only 26 cents per pound. Thus it appears that king salmon production, at least in Southeast Alaska, is approximately at the economically optimal level, although increases may result in benefits greater than the costs.

Sensitivity Analysis: High and Low Price Predictions

The analysis to this point has been based entirely on the mid-point estimates for prices. In this section, we consider the range of estimates based on high- and low-price scenarios. The high price scenario was created by inflating the value of all exogenous variables which had a positive effect on prices by 10%, and deflating all variables which had a negative effect on prices by 10%. The low price scenario was created by doing just the opposite. In this sense, the high- and low-price scenarios should be viewed as best and worst cases.

The RSA requested sensitivity analysis for each of the first six alternatives (cases 1-6). However, the range of values considered in the sensitivity analysis was too extreme for the mathematical demand model to produce a solution for several of the cases. Thus, for cases 3, 4a, and 5 we do not report a low-price scenario. The high price scenario is presented for all cases.

The results are presented in Table 8. For ease of comparison, we reproduce the mid-price results from Table 6. Each entry in Table 8 represents the present value of net benefits (producers' surplus minus hatchery costs), over 30 years, using a 4% discount rate.

Table 8: Sensitivity Analysis for Selected Enhancement Alternatives

(present value in millions of 1992 dollars, future values discounted at 4% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
<i>Case 1: current levels</i>						
low	886.98	247.07	255.36	102.32	672.83	2164.56
mid	993.40	276.55	288.69	126.63	737.78	2423.05
high	1173.08	325.67	341.24	162.96	836.48	2839.43
<i>Case 2: planned levels</i>						
low	854.67	264.76	242.79	127.14	650.14	2139.50
mid	955.09	296.22	274.52	157.15	713.85	2396.84
high	1124.57	348.88	324.67	201.84	809.71	2809.67
<i>Case 3: eliminate all salmon enhancement</i>						
mid	1109.59	288.91	309.48	144.29	863.69	2715.95
high	1317.74	337.80	357.21	164.53	958.78	3136.05
<i>Case 4a: increase all enhancement by 15%</i>						
mid	978.03	274.76	277.56	114.16	674.43	2318.94
high	1154.19	324.06	330.28	151.70	772.33	2732.56
<i>Case 4b: decrease all enhancement by 15%</i>						
low	873.69	281.13	278.24	284.53	823.87	2541.47
mid	1005.97	278.71	288.60	145.08	736.28	2454.63
high	1188.75	327.79	340.19	180.84	832.95	2870.51
<i>Case 5: eliminate all pink enhancement</i>						
mid	1016.91	271.01	312.64	95.02	874.81	2570.39
high	1200.71	319.92	366.87	123.08	983.00	2993.58
<i>Case 6: eliminate all red enhancement</i>						
low	923.13	231.62	213.91	55.60	624.41	2048.67
mid	1036.43	262.67	253.90	94.83	767.95	2452.41
high	1209.47	328.45	301.76	143.42	818.05	2801.15

The first point to observe about the data in Table 8, on the previous page, is that the magnitude of the differences between the high-, mid-, and low-price scenarios is on the order of \$400 million dollars in present value. That is to say that if the high price scenario occurs instead of the mid point scenario, the increase in return to the state is about \$400 million dollars in present value over the 30-year planning horizon. If the low-price scenario were to occur, the state would lose on the order of \$400 million. This is a difference of plus or minus 15% approximately, depending upon the specific alternative followed.

Taking the current case as an example, the mid-price estimate is of a 30-year return of \$2,423 million in present value over 30 years. This is equivalent to an annual net return of about \$135 million. The low-price scenario estimate if current enhancement levels are maintained is of a 30-year present value return of \$2,164 m, or an annual net return of about \$120 million. If the high-price scenario were to occur, the statewide net return would be \$2,839, or an annual return of about \$158 million.

The second point to observe about the data in Table 8 is that at the statewide level, the relative rankings among alternatives remain virtually unchanged. The one exception to this is that under the high-price scenario, case 2 rises from sixth to fifth in the rankings out of the seven cases for which sensitivity analysis was conducted. Of the four cases for which low-price sensitivity analysis was conducted, there are no changes in relative rankings at the statewide level.

A third point is with regards to the range of differences between the alternatives. Under the mid-point scenarios, the difference in present value between the highest and lowest valued alternatives (cases 3 and 4a, respectively) is \$397 million. Under the high-price scenario, the range is slightly less, \$372 million. Under the low-price scenario, the difference between the highest and lowest valued cases is in the same range, about \$393 million. However, the low-price scenarios for the two highest valued alternatives (cases 3 and 5) and the lowest valued alternative (case 4a) are not reported. By comparison, the difference between the extreme cases under the low price scenario (case 4b and case 6) differ by only \$39 million in present value under the mid-price scenario, and by \$106 million under the high-price scenario. Thus, it is possible that the differences between the highest and lowest alternatives under the low-price scenario differs by much more than is suggested by the numbers we were able to report.

For the most part, the regional changes are similar to the statewide changes. For none of the regions do the rankings change for the high-price scenarios relative to the rankings under the mid-price scenarios. For the low-price scenarios, the relative rankings remain unchanged for Western, Cook Inlet, and Kodiak. However, for Prince William Sound and Southeast, the relative rankings under the low-price scenario are different from either the mid- or high-price scenarios. The case that changes in these two regions is case 4b, where all enhancement production is lowered by 15%. Under the mid- and high-price scenarios, this alternative is ranked third or fourth (among the seven alternatives for which sensitivity analysis was conducted) for most regions. However, under the low-price scenario, this option is ranked first for Prince William Sound and for Southeast. Furthermore, under the low-price scenario, the actual return to these two regions is higher than what would occur under mid-price scenario. In Prince William Sound, the return is even higher than the highest possible return for the high-price scenario.

We suspect that this result is due to two factors. First, 4b has the most drastic reduction for which the demand model could be made to converge. Under this scenario, pink salmon prices are predicted to reach record high levels. Under the low-price scenario, factors which in general contribute to low prices were inflated, and factors which generally contribute to high prices were deflated. However, factors that contribute to high prices of the high-valued species are not necessarily factors which contribute to high prices for low-valued species. We suspect that the combination of these two effects lead to the result that alternative 4b has such a large positive return to Prince William Sound and to Southeast under the low-price scenario. Since this case, along

with all of the cases 2-4, are subject to the limitations we discussed in section I, this result should be viewed with caution.

Sensitivity Analysis: Effect of the Discount Rate

A final area where sensitivity analysis was conducted was with respect to our choice of discount rate. The discount rate is used by economists to reflect the tendency of people to discount the future. At the individual level, this occurs because people are impatient and because the future is uncertain. It also reflects the fact that a dollar earned today may be used for activities which provide a return. A dollar earned tomorrow does not provide this option.

The choice of discount rate is generally only important when the distribution of costs and benefits is different across time. If all costs occur in the present and all benefits occur in the future, a high discount rate will make the project look less appealing and a low discount rate will make it look more appealing. Social rates of discounting are generally thought to be lower than individual rates of discounting because some things which are losses to an individual are benefits to someone else in society. Low discount rates are often defended on moral grounds. Many environmentalists, for example, argue that we have no moral right to discount the future. On the other hand, when the future is very uncertain, such as in times of war or when the industry is undergoing very rapid structural change, a high discount rate may be appropriate.

We chose a discount rate of 4% for our central analysis. In this section, we examine the results under assumptions of 0% and 7% discount rates. At a 4% simple annual discount rate, a benefit of \$1.00 earned in the 30th year of a program would be worth \$0.32 in present value today. By contrast, a discount rate of 0% would value the \$1.00 earned 30 years hence at \$1.00, and a 7% discount rate would value it at only \$0.13. The mid-price net benefits results from Table 6 are reproduced in Tables 9 and 10 for discount rates of 0% and 7%, respectively.

The main result from Tables 9 and 10 is that the rankings of the various alternatives remains unchanged across the various discount rates. In particular, the rankings of the highest-valued alternatives do not change (cases 3, 5, 7b, 4b, and 11a, respectively from highest to lowest) and the rankings of the lowest valued alternatives do not change (cases 4a, 7a, and 2, respectively from lowest to highest). Furthermore, in percentage terms, the highest-valued alternative (case 3) remains between 11 to 13% higher than under the current enhancement levels (case 1), and the lowest-valued alternative (case 4a) is between 4 to 5% lower than the current case.

Essentially, the lesson that comes from comparing Tables 6, 9, and 10 is that the distribution of costs and benefits under the hatchery program is fairly constant over time for each of the alternatives. Since the benefits of the enhancement program extend over the entire planning horizon, it follows that the costs of the enhancement program are also distributed fairly evenly over the entire 30-year period.

Table 9: Net Benefits by Enhancement Alternative (0% discount rate)

(present value in millions of 1992 dollars, future values discounted at 0% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE TOTAL
1	1700.36	451.11	499.07	224.36	1282.98	4157.89
5	1743.25	438.78	543.63	154.22	1529.34	4409.22
6	1779.38	458.76	439.48	208.89	1310.07	4196.58
7a	1694.53	452.56	485.68	209.71	1239.38	4081.87
7b	1706.17	451.06	507.98	230.56	1320.49	4216.26
8a	1689.64	451.50	506.78	225.71	1265.96	4139.57
8b	1711.29	452.16	491.37	223.50	1286.98	4165.30
9a	1698.72	450.37	494.98	219.12	1288.38	4151.57
9b	1702.31	451.82	500.12	223.20	1260.31	4137.76
10a	1698.45	449.69	498.31	231.29	1280.18	4157.91
10b	1701.52	451.54	499.67	223.30	1278.58	4154.61
11a	1699.54	452.40	498.68	231.61	1285.78	4168.01
11b	1701.42	451.52	499.45	224.46	1273.00	4149.85
2	1624.56	490.90	471.51	286.32	1239.02	4112.31
3	1918.84	467.67	533.37	231.52	1474.06	4625.45
4a	1671.50	448.48	479.91	206.97	1193.25	4000.11
4b	1724.08	453.94	498.61	255.26	1276.39	4208.27

Table 10: Net Benefits by Enhancement Alternative (7% discount rate)

(present value in millions of 1992 dollars, future values discounted at 7% discount rate)

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE TOTAL
1	718.81	208.12	207.09	89.27	526.79	1750.10
5	734.85	205.15	223.19	72.07	621.41	1856.67
6	748.05	215.38	188.30	84.74	538.85	1775.32
7a	716.61	208.63	201.81	81.08	509.20	1717.34
7b	721.02	208.38	210.39	93.01	541.47	1774.27
8a	715.12	207.74	209.58	88.92	514.60	1735.96
8b	722.62	209.07	204.63	89.59	528.63	1754.54
9a	718.24	207.86	205.26	86.46	522.69	1740.50
9b	719.49	208.37	207.56	88.94	519.55	1743.91
10a	717.47	207.50	206.79	91.88	523.09	1746.72
10b	719.22	208.34	207.32	88.95	525.66	1749.49
11a	718.53	208.70	206.96	92.19	524.65	1751.03
11b	719.16	208.32	207.22	89.31	523.88	1747.90
2	694.39	220.29	197.93	108.37	510.47	1731.45
3	795.96	218.65	222.55	109.90	625.70	1972.77
4a	708.60	206.69	199.08	78.76	474.49	1667.57
4b	727.13	209.99	207.13	102.82	527.10	1774.17

IV. DISCUSSION OF FINDINGS

According to our estimates, the most the enhancement program provides in additional benefits as measured by producers' surplus is \$147 million in present value over 30 years. The enhancement program, however, costs between \$300-500 million in present value over the same time period. However, as mentioned previously, this analysis only considers benefits and cost to the commercial salmon fisheries. Other user groups such as sport and subsistence fishermen were not included. In addition, indirect impacts such as employment and income in fish processing and support services were not included.

None of the alternatives involving increases in enhancement production results in increasing net benefits to any significant degree.¹⁴ On the other hand, all of the major reductions in the enhancement program (cases 3, 5, 6, and 4b), as well as smaller reductions for pink salmon (case 7b) resulted in large increases in net benefits.

One significant caveat needs to be mentioned. While it appears that a reduction in enhanced fish would be warranted from an economic point of view, it does not follow that all hatcheries should be forced to shut down. However, *if a region wants to continue with a hatchery program, the most cost effective and marketable production level and composition would result if the program were entirely funded by the local user groups rather than subsidized by the state.* If the fishermen and facilities 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.

If the state reduces or discontinues funding of the enhancement program, 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. 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 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 market in the long run. However, by maintaining some hatchery production, prices may remain sufficiently depressed to prevent expansion in those areas. As long as the price is not driven down to the level that it would reach if these other producers do enter the market, the hatchery dollars may be well spent. However, this is not a strategy which can remain viable over the long run.

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, scaling back the enhancement program, and especially the pink salmon program, would increase net benefits.

¹⁴Increasing the king salmon enhancement program production by 15% resulted in generation of estimated additional benefits (relative to current) of \$3.4 m over thirty years in present value. It is unlikely that this is statistically significant.