FRED Reports

AN ANALYSIS OF THE NET BENEFITS OF EXISTING AND PROPOSED ENHANCEMENT PROJECTS FOR THE STATE OF ALASKA
Prepared for
the Mini-Cabinet on Fisheries

by
Jeff Hartman
Number 64

Alaska Department of Fish & Game
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Enhancement and Development

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Alaska Department of Fish and Game
Division of Fisheries Rehabilitation, Enhancement, and Development (FRED)

Don W. Collinsworth
Commissioner

Stanley A. Moberly
Director

P.O. Box 3-2000
Juneau, Alaska 99802

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ABSTRACT

Governor Sheffield, in a memo dated 1/10/84, directed his Fisheries Mini-Cabinet to "evaluate the costs and benefits of current fisheries appropriations and programs with immediate focus on the state's salmon enhancement activities, including private non-profit (PNP) hatcheries and regional associations."[1] Following this directive, the Department of Fish and Game (ADF&G) has participated in an analysis of the statewide hatchery program. Others that have also contributed data and information to the analysis are the Department of Commerce and Economic Development (DCED) and the Commercial Fisheries Entry Commission (CFEC).

This analysis includes a forecast of catches for natural and hatchery stocks of salmon as well as hatchery stocks of lake-stocked trout and grayling. A benefit-cost study of each hatchery project is also included. Both public (state owned) and PNP facilities are included in the evaluation. The resulting information has enabled the determination of long-range net benefits of the aggregate hatchery program. The methods used in the analysis address, from the perspective of the residents of the State of Alaska, the question of whether these benefits exceed projected public and private costs. The technique most suited to this purpose is benefit-cost analysis.

The results of the analysis address both the quantity and value of the sport-caught fish and the commercially caught fish from the enhancement projects. The enhancement-program production (or harvested output) is treated as an increment to be added on to several probable levels of future natural-stock harvests.

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[1]Fisheries Mini-Cabinet members included Don Collinsworth, Commissioner of ADF&G; Richard A. Lyon, then Commissioner of DCED; Richard A. Neve, then Commissioner of DEC; and John Katz, then Governor's Office/State-Federal Relations.

The maximal annual number of harvested hatchery fish will be reached by the year 2000; commercial and sport fishermen will harvest between 21.04 and 28.63 million fish.

In the analysis of net benefits for the commercially harvested salmon, a number of variables and models are tested. Of these, the most sensitive are (1) price-forecasting model type (linear vs semi-log), (2) natural-stock harvest over 25 years, (3) hatchery-fish survival, and (4) commercial-fish catch rate.

The results of the study suggest that if the natural-stock catch remains at the middle-catch ranges of 66 to 86 million salmon (87 to 115 million salmon with enhancement), the *present value*[2] of the net benefits (NPV) will range from below zero ($-178.6 million) to significantly above zero ($344.8 million), depending on price-forecasting model-type. A NPV of zero is equivalent to breaking even. If the catch for the naturally produced stock in the commercial fishery falls to the lower-catch ranges of 45.5 million naturally produced salmon (for a total of 66.1 to 75.1 million fish) the NPV will clearly be positive with both forecasting models. If the catch for the natural stock stays at the higher catch range of 101 million salmon for 25 years (total of 122 to 131 million harvested salmon) NPV is estimated to be between zero and well below zero.

The profits (or consumer surplus) from the sport fishery are only roughly estimated in the analysis. Estimates vary from slightly above zero (a *present value* of $25.2 million) to a higher *present value* of $362 million. The low estimate for the value of the sport fishing effort from the enhanced stock of close to zero has little effect on the overall NPV of the enhancement program. The NPV of the middle-catch ranges (natural stock harvest of 66 to 86

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[2]Italicized words in the text may be found in the GLOSSARY.

million fish) is left at approximately zero. When the NPV of the more optimistic sport-fish value is added to the NPV of the commercially harvested fish, the NPV of the entire enhancement program appears to be positive in all of the low-, middle-, and high-catch cases tested.

The testing of variables in this analysis results in a broad range of outcomes. It is apparent that some additional work in the evaluation framework and simulation models will be required, if the involved agencies are to be expected to fine-tune investment decisions (see Appendix F for recommendations). Some of the steps in improved forecasting include greater precision in price forecasting models, greater precision in sport-fishing surplus estimates, and a modeling framework and software that could interactively and stochastically deal with more sophisticated recruitment/fishery exploitation models and economic models.

KEY WORDS: economics, evaluation, benefit-cost, enhancement, salmon, hatcheries, forecasting

INTRODUCTION

Statement of Governor's Policy Directive

The Governor's policy directive to the Fisheries Mini-Cabinet is stated in the form of a general objective: "evaluate the costs and benefits of current fisheries appropriations and programs with immediate focus on the state's salmon enhancement activities, including private non-profit (PNP) hatcheries and regional associations."

To address this directive, it has been necessary to ask the question: "At a conservative level of investment, does the state generally expect positive net economic benefits from existing and proposed state and PNP projects from a state accounting perspective?" This question can now be addressed using the rigorous evaluation technique of benefit-cost analysis. To conduct this analysis, modifications were made to an economic-feasibility model developed to evaluate state-owned fishery-enhancement projects (Hartman and Rawson 1984).

General Background on Economics and Benefit-Cost Analysis

Benefit-cost analysis is a method of evaluating an investment or a group of alternative investments. In long-term investments the analysis is made by forecasting the benefits and costs that occur over a series of years. The *present value* of the stream of net benefits is then estimated by using an appropriate discount rate.

The "transaction" is an important concept in economics and benefit-cost analysis. A transaction occurs when two or more people voluntarily exchange something of value; e.g., exchange of currency for groceries at the local supermarket. People will only participate in a transaction when they perceive that they will be made better off by the exchange. In economic terminology, such a transaction is considered to be a *pareto improvement*, that is, an economically efficient one. In a potential pareto improvement, some people may be made better off and some may be made worse off. This means that benefit-cost analysis is based on a modified economic-efficiency concept. In the potential or modified-efficiency approach, a project is considered efficient if the present value of the benefits minus the present value of the costs result in positive *net benefits*.

In projects of this type, where a portion of those affected may be made worse off, it might be feasible to apply some mechanism for redistributing wealth to compensate losers. If the costs of implementing the redistribution are small, compared to the net benefits of the investment, an estimate of this compensation can be made. Any effort made to estimate the amount of the compensation must include all relevant costs; e.g., opportunity, transactional, and governmental costs. In the potential pareto-improvement approach used in benefit-cost analysis, this step is usually not taken. The distribution of benefits and costs, which are not usually considered explicitly in the benefit-cost criterion, must be dealt with in some other manner. Where possible, it is worthwhile to make decision makers aware of the groups that will be made better off and those that will be made worse off by transactions related to a given project.

When investigating an investment alternative or resource allocation decision, benefit-cost analysis requires the consideration of two options: one with and the other without enhancement. For the purpose of this study, each computer simulation uses with- and without-enhancement calculations for estimating the present value of the net benefits. No consideration will be given to enhancement investments, other than the ones stated in the study. However, the difference between the net benefits of the with-enhancement case and without-enhancement case must result in at least a *normal* (break even) rate of return, if discounted benefits are to exceed discounted costs. The data reported in the result section of this document are the difference in the net benefits of the with- and without-enhancement approach; the estimated catch for both approaches is reported in the RESULTS section.

Accounting Perspective:

An accounting perspective defines the group of people the economic analysis is focused on as well as the relevant costs and benefits. For example, a private individual evaluating the profitability of an investment will generally count only the benefits and costs affecting his family or business; the *external effects* on others will not be considered. Similarly, when a government evaluates an investment, it will generally count the benefits and costs affecting only its citizens. For the purposes of this study, external effects on noncitizens are excluded.

The changes in benefits and costs of the fishery, due to the implementation of an enhancement program, will be evaluated from (1) a state accounting perspective that focuses on the residents of the State of Alaska and (2) a modified national-accounting perspective that would include U.S. citizens. The analysis produces a present value of the net benefits (NPV) at both the state and modified national level. We refer to the national-income perspective as modified, because none of the net benefits to the retail-level consumer of commercially caught salmon are being accounted for; e.g., if increases in Alaskan harvests of salmon produce more fish at lower prices in the domestic market, consumers in the U.S. will be made better off. If this occurred, some *consumer surplus* at the retail level may be attributable to the enhancement program.

Since the state's accounting perspective requires data on whether the benefits of the projects stay in the state or leak out of it, the CFEC has provided estimates of residency fractions for commercial fisheries. The fraction represents the portion of fishermen in a management area that are residents of the state. These constants are multiplied against the net benefits for a particular commercial fishery to determine economic profits from the state perspective (Focht 1984). For this analysis we have assumed that residency is a reasonable estimator of state vs. national income.

In the state-accounting perspective, benefits and costs attributable to nonresident fishermen will be viewed differently than those of resident fishermen, because it is assumed that profits to nonresidents will be dispersed outside of the state and have no appreciable effect on the welfare of Alaska. An estimated residency-harvest fraction has been applied to sport-harvested salmon as well as to the commercially harvested salmon for the state-accounting perspective. The modified national-accounting perspective makes no distinction between state and national residency, and the residency factors are not applied.

Estimating Social Benefits of an Enhancement Investment:

Some transactions are characterized by a voluntary exchange of *goods*. Goods that are voluntarily exchanged between two or more people are called "market goods". Other transactions do not involve voluntary exchange between two or more people, and these are often referred to as "nonmarket goods", e.g., recreational fishing.

The benefits associated with both market and nonmarket goods can be estimated through use of a *demand function*, which is a mathematical equation (P=f[Q]) describing what a consumer (or consumers) is willing to pay for a given amount of the goods. A typical demand function is represented by a downward sloping *demand curve* (Figure 1).

In this study the benefits associated with the commercial fishery are based on the first consumer (the commercial fisherman) and

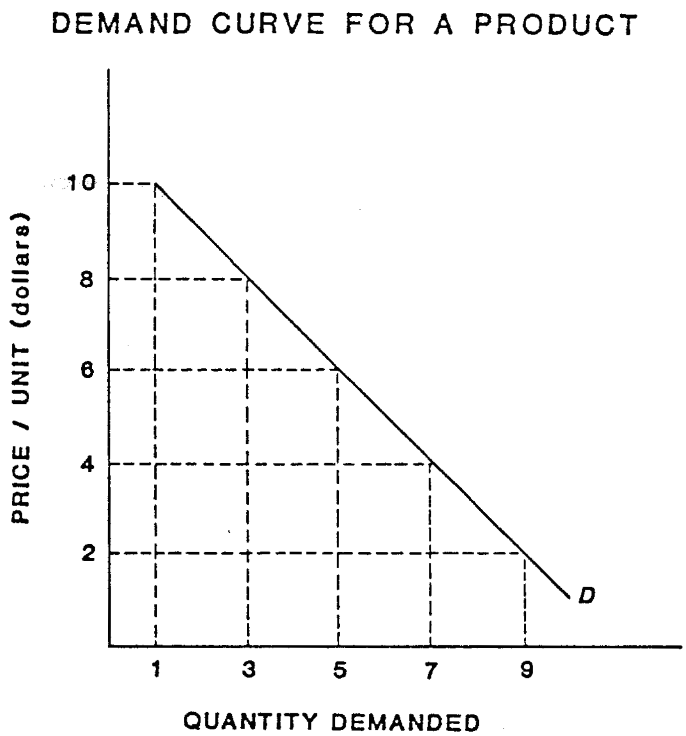

FIGURE 1. Hypothetical demand curve for a product.

The demand curve allows us to evaluate the effect of one influence (price) on the amount of a product (or good) that people choose to consume. The demand curve represents the relationship between the amount of a good that people are ready, willing and able to buy, and its price, holding constant other factors such as income, expected future prices, and prices of other goods. For example, if the price were \$8 per unit, three units would be demanded. On the other hand, if the price were \$4 per unit, seven units would be demanded.

his "willingness to pay" for the opportunity to catch hatchery fish. The benefits associated with sport-caught fish are focused on the final consumer, namely the sportfisherman and his willingness to pay for hatchery-produced sport-fishing opportunities.

Estimating Social and Opportunity Costs of an Enhancement Investment:

Costs, measured in economic terms, go beyond the simple *accounting costs* of a given project. In state government, accounting costs are capital or operating dollars spent from the state treasury. Economic costs include *opportunity cost*. The opportunity cost to society includes the highest valued opportunity foregone when an investment is made or when any economic activity is undertaken. This may be the net benefits from another potential investment or several investments. This lost opportunity to society is considered an important part of calculating the cost of an investment.

In a benefit-cost analysis, it is often impractical to consider all the foregone activities of an investment. A widely used method of partially accounting for the opportunity cost of an investment is through the use of a *discount rate*.

The interest rate used for discounting may approximate the interest from other relevant investment alternatives. If an identical interest rate is used for several proposed investments, it allows the analyst to compare the profitability of investment alternatives. For this model, we have chosen a real interest rate of 3%. The real interest rate is the *nominal interest* rate less the rate of inflation.

The interest rate for this analysis has been used and endorsed for use in other state investments and has been used for an earlier benefit-cost analysis for fisheries enhancement (Hartman and Rawson 1984). It has also been recommended by the trustees of the Permanent Fund for applying to state-government investments (Jim Rhode, personal communication). Finally, a real interest rate of 3% was used by the Alaska Power Authority for their analysis of the Susitna hydro-dam project (Yould 1982).

The real interest rate used for discounting in this analysis is applied to future benefits and costs for estimating the present value of benefits (B_{pri}) and the present value of costs (C_{pri} and C_{pub}). In this way we can see what any future benefit or cost will be worth in today's dollars.

Estimating Present Value of the Net Benefits for this Investment:

In a publicly funded project, it is necessary that our accounting equations deal with both private and public benefits and costs. The profits from each investment alternative are determined with equations that calculate the NPV and benefit-cost ratio of those cases. The equations applied to this study are the conventional equations used by economists to conduct benefit-cost analysis on publicly funded projects (Randall 1981):

$$B_{pri} - C_{pri} - C_{pub} = \text{Present value of net benefits (NPV)} \quad [1]$$

$$\frac{B_{pri} - C_{pri}}{C_{pri}} = \text{Benefit-cost ratio (i.e., this ratio should never be reported without the NPV)} \quad [2]$$

Where:

B_{pri} = The present value of the benefits (revenue) to the private sector resulting from a change in the amount or value of product harvested due to the enhancement project.

C_{pri} = The present value of the costs to the private sector resulting from the enhancement project, (e.g., cost of harvesting and/or processing, etc.).

C_{pub} = The present value of the public costs resulting from producing and managing enhanced stocks of fish (e.g., operational cost, construction cost and planning costs of the enhancement facility).[3]

MATERIALS AND METHODS

Economic and Procedural Assumptions for this Analysis

In order to address the Governor's policy question using benefit-cost analysis, major modifications were made to an economic-feasibility model developed by Hartman and Rawson (1984). This model was designed to evaluate state-owned fishery-enhancement projects. The modified version of the model has three components: the Hatchery Broodstock Development (HBD) system, the price-forecasting system, and the facility benefit-cost (FBC) system.

The HBD system projects the change in future salmon harvests from production for each facility, based on current levels of production, plans for expansion, life-stage survival assumptions, and fishery-exploitation expectations. The second component, the price-forecasting model, predicts the change in Alaskan salmon ex-vessel prices (price paid at landing) and the change in total revenue resulting from investment in enhancement projects. The third component, the facility-benefit cost (FBC) system,

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[3]The reader may note that the terms B_{pri}, C_{pri}, and C_{pub} do not include B_{pub}, which would account for the social benefits to the government labor force. While some social benefits may accrue to the government labor force, they are not included in this analysis.

simulates the incoming revenue and cost streams from harvest predictions made in the HBD model.

Since benefit-cost analysis uses a present and future-oriented approach to the evaluation of a project, past costs (before 1984) become irrelevant because costs that have already been incurred are irretrievable. To accomplish the future-oriented projection, the FBC model includes accounting functions that allow computation of present values of future benefits and costs of project alternatives.

In this study, the year 2003 marks the end of the economic life for hatchery operations. Since salmon will continue to return for several years after the 20th year of operation, benefits and costs of the fishing fleet are computed to the 27th year of the analysis. A number of current studies in salmon hatchery benefit-cost analysis have used a 20- to 30-year economic life to measure fishery-enhancement production and revenues (Orth 1980; Barclay and Morley 1977). Economists have chosen this time interval for hatchery investments because (1) it corresponds to the average life of the major components in the hatchery, (2) the discounted value of the dollar (today's value of the future dollar) after 30 years is small and benefits and costs have a less significant influence on the net-present value of the investment, and (3) our ability to choose probable alternative investments diminishes after 30 years.

In benefit-cost analysis, the scale of the production increment may have a great effect on the assumptions used in the analysis. For example, the assumptions used in evaluating production from a single hatchery investment in Kotzebue, Alaska that would involve a very small increment in the salmon catch is quite different from the assumptions used for an extremely large increment such as the projected State of Alaska and PNP enhancement production. The analysis undertaken here focuses on a very large increment, because the Governor's policy question addresses the entire salmon enhancement program. Thus, we are treating the enhancement output as one large investment and addressing the question of whether the overall enhancement production from these series of investments is economically efficient.

This is useful for the purpose intended, but its application is somewhat limited when looking at smaller increments. For several reasons it is difficult to focus on the production output of individual hatcheries. First, the price forecasting lumps together species and catches from various areas of the state so that it is not feasible to differentiate between the efficiency of an investment by management area or hatchery. Second, the method of sport-fish valuation does not allow for a breakdown of benefits at the hatchery level, because data are lumped together for a series of sites. Finally, we have focused on a with-investment and without-investment analysis that intentionally looks at the cumulative output from state and PNP projects. To investigate individual hatchery-efficiency scenarios, the analyst would be required to simulate with-investment and without-investment schemes for each individual hatchery. While this is a feasible task, it is beyond the scope of this project.

Assumptions for Private Non-Profit Hatcheries:

The with-enhancement analysis considers data gathered from both state-owned and PNP hatcheries. Managers or corporation representatives of the state's 21 PNP hatcheries have been interviewed so that present "permitted" capacity and anticipated future capacity (based on plans for expansion) can be projected. The interviews were conducted between 1 May and 12 June 1984 by FRED Division PNP staff. The information obtained from officers of the regional (aquaculture) associations and private hatcheries reflects their proposed planning assumptions in effect during this planning period. The purpose of interviews with PNP operators was to solicit their informed guess of aquacultural, biological, and fishery assumptions applicable to predicting future production of their facility. The variables are used to build and update the benefit-cost model.

After collecting PNP assumptions, a review of the data was conducted to finalize the biological and fishery criteria, production numbers, and cost assumptions to be used in the analysis. The review was conducted by ADF&G and DCED working-level members appointed by the Fisheries Mini-Cabinet. Data from each PNP hatchery have been individually reviewed to identify differences between state and PNP assumptions.

Of the hundreds of capacity, survival, and operating-cost assumptions that were projected by PNP operators and State analysts, considerable agreement existed in values collected for the analysis. A few differences in biological assumptions were expected in the review process. Where major differences between two projections were encountered, historical data for a facility were major considerations in developing "most likely" assumptions for the analysis. Where historical hatchery information was limited, biological assumptions have been applied that are consistent with similar facilities in operation for a long time; e.g., species cultured, lifestage at release.

Governor Sheffield's original policy directive calls for an accounting of the benefits and costs of regional associations; however, this analysis is focused only on the performance of hatcheries. While it is true that hatchery activities constitute a major portion of their efforts, this analysis could not be extended to allow for ranking regional associations in terms of efficiency. Appendix G includes recommendations for evaluation of individual hatcheries that would be more helpful in ranking investments undertaken by state government or regional associations.

Assumptions for Biological and Fishery/Population Dynamics:

To estimate the *change in total revenue* for the commercial fishery resulting from a specific fishery-enhancement project, the increase in the total salmon harvest for each species of salmon must be projected. A first step in this process is to make a forecast of future natural salmon stock harvests. A second step is to estimate the number of fish harvested in future years with the added enhanced stock. Thus, the study establishes harvest estimates that are with and without enhancement.

Some general features of the without-enhancement analysis:

1. The without-enhancement analysis assumes that all fishery-enhancement and rehabilitation projects will be halted immediately and that such fishery policies will continue to be in effect through the year 2003. The only Alaskan sources of salmon that will exist throughout this period will be from the natural stocks.

2. The natural-stock catch estimate for Alaskan salmon is determined by an evaluation of historical catch data. Moving averages as well as trend analysis are used to focus on several probable levels of catch. No recruitment functions that might involve forecasting based on catch, escapement, and other variables are used (*see* appendix B for detailed explanation).

3. The commercial harvest of each salmon species is not separated into catch by a management area or by gear types in a management area.

Some general features of the with-enhancement analysis:

1. The with-enhancement analysis, which combines the natural-stock and enhancement-stock harvests, assumes that the state and PNP hatcheries will continue production as planned. For the purposes of this analysis, the estimated harvest of enhancement-produced fish will be added to the natural-stock harvest.

2. The commercial harvest of the enhancement-produced fish is determined by estimating the number of adult hatchery

salmon produced and then estimating the number of fish to be caught in the fishery each year.

3. The estimated harvest from a given hatchery is assigned to a management area and separated into gear types. The distribution of salmon harvested between gear types is assumed to be constant over time. This information is used later in the economic part of the analysis.

Since the scope of our economic-evaluation project is limited, many simplifying assumptions have been made regarding fishery population dynamics, management, fleet behavior, and consumer behavior. For example, this model does not contain some of the more involved mathematical computations that deal with non-linear or stochastic-recruitment functions, density dependence, competition, and interaction. Also it does not include a thorough testing of all alternate price-forecasting models that might have more (or less) precision. A far more comprehensive evaluation of some of these components is possible with benefit-cost analysis and more elaborate fisheries models. The effort would require the modeling of a wide range of future management/fishery/enhancement alternatives. Such an effort is beyond the resources of this project.

Estimating Natural-Stock Harvests for the Commercial Fishery:

To conduct this study, a forecast of Alaskan natural-stock harvest has been made by evaluating historical catch information for salmon. Because of the variability in catch and factors influencing those catches, it is not realistic to forecast a single value that represents the future natural-stock harvest for all salmon species in the state.

Forecasts of several natural-stock harvests were derived from data supplied by both the Commercial Fisheries and FRED divisions of ADF&G. The projection are for yearly statewide harvests for all species. Each case is a forecast of average catch that is

Table 1. An estimate of natural stock harvest in millions of salmon by species and case.[a/]

	Pink	Chum	Sockeye	Coho	Chinook	Total
Case 1.	25.0	4.7	11.7	1.6	0.4	43.6
Case 2.	37.9	7.1	17.7	2.4	0.7	66.2
Case 3.	44.3	8.3	20.7	2.8	0.8	77.3
Case 4.	49.5	9.3	23.1	3.1	0.9	86.3
Case 5.	62.9	8.1	25.4	2.9	0.76	101.5

a/ Note: Projected harvests by species (for case 1 through 4) have been computed by taking the arithmetic mean of the catch rate for each of the five species over the last 20 years of salmon catches. During years of higher harvests, the apportionments of coho and chinook catches consistently vary downward from the means of the 20-year average. Thus, catch fractions for case 5 have been estimated from the maximal total catch taken from the four-generation moving averages (Frohne 1984).

Table 2. Commercial fish harvest weights for natural stock as computed from catch and production statistics from 1979 to 1983.

	Pink	Chum	Sockeye	Coho	Chinook
Average weight per adult salmon					
kg	1.62	3.56	2.73	3.36	8.53
(lbs)	3.56	7.85	6.01	7.40	18.78
standard deviation					
kg	.15	.13	.16	.09	.21
(lbs)	.34	.28	.35	.20	.46

Assumptions in Estimating Proportion of Hatchery-Produced Salmon Stock in the Commercial Fishery:

The forecast of long-term catches of naturally harvested fish has been directly estimated from historical catch information. A slightly different approach is used for estimating the annual harvests from the enhancement production. A first step involves estimating the total number of new fish available to the fishery. The second step involves application of a catch rate so that the total number of harvested fish may be estimated. In this analysis, the catch rate is a constant computed from the historical catch and escapement. The proportion [catch/(catch + escapement)] may be computed for a single year or a number of years. It is multiplied by the total number of hatchery-produced fish to estimate hatchery catch. In part of the analysis, it is applied to all hatcheries over the life of the analysis. In a second case, it is computed annually and applied to each hatchery based on a scheme that maximizes hatchery catch.

Forecasting catch rates of hatchery fish also requires dealing with considerable uncertainty and variability that may affect exploitation rates in a salmon fishery. It is not possible to thoroughly treat principles of biological systems and fleet dynamics here, but a few of the more notable influences on exploitation rate will be addressed. The abundance of fish in the common-property fishery may result in changed exploitation rates. The number of stocks and their migration timing may also affect exploitation rates. Significant differences in exploitation rates may exist in a so-called mixed-stock fishery, compared to those in a nonmixed-stock fishery. Mixed-stock fisheries can occur when two or more stocks of fish are exploited simultaneously in the same location. Mixed-stock fisheries can create problems when fishery managers are not able to direct the fleet to harvest desired proportions of the stocks available. Escapement of weaker stocks to spawning grounds can be jeopardized under such conditions. Management or enhancement actions that alter the strength of an existing fish stock in this type of fishery may result in changed exploitation.

There are mathematical techniques for predicting the reaction of fishermen to changing environmental, economic, and management conditions (Clark 1976) that could be applied to estimating the exploitation of hatchery fish. Such techniques, however, are not used in this study; instead, an alternative approach is used. It is sufficient to estimate the probable bounds of hatchery fish exploitation from the statewide production. Thus, we have assumed two cases of commercial harvest fraction for all hatchery fish.

Assumption I is a harvest rate at a constant of 67% over the entire commercial catch of enhancement-produced fish. This catch assumption implies (somewhat pessimistically) that fisheries managers will not find effective ways of dealing with mixed-stock problems potentially occurring between naturally and hatchery-produced fish; consequently, in the presence of uncertainty they will choose conservative exploitation rates that intentionally restrict harvests of naturally produced salmon to achieve targeted levels of escapement.

Assumption II is a maximal hatchery-harvest rate where the commercial harvest is the difference between total production less required escapement to the hatchery and stream. Generally, this assumption results in a much higher yield of enhanced fish. It assumes, more optimistically, that managers will generally find ways of dealing with mixed stocks so that increases in the total fish numbers (due to enhancement) will not result in losses of naturally produced salmon.

Assumptions for Enhancement Facilities for Commercial and Sport Valuation:

Development of fish-cultural, engineering, biological/environmental, and fishery assumptions are part of the planning process for any hatchery. The assumptions may be developed for part of a hatchery design, operational start-up, or management of a newly created fishery. The assumptions are essential variables for the biological and economic simulations in this analysis. The equations for simulating the results of the hatchery broodstock development and fishery catches (in the HBD model) are explained in detail in Appendix A of Hartman and Rawson (1984). The development of hatchery assumptions was accomplished through interviews with PNP and state hatchery operators and a final review process by assigned staff from state government. Hatchery assumptions include (1) broodstock development information, (2) survival rates, (3) commercial and sport fishery interception rates, (4) fecundity of female fish, and (5) the expected contribution of hatchery fish to stream escapement. Some key assumptions are discussed in greater detail in the following sections. All quantitative assumptions are formally listed in Appendices C through F.

Assumptions for Life-Stage Survival Rates of Enhancement-Produced Fish:

To estimate the number of fish that are harvested by participants in the commercial fishery or sport fishery, it is necessary to estimate the number of adult salmon produced. To be useful for the benefit-cost analysis, the estimate should forecast a production that is in addition to the natural stock.

The recruitment of the hatchery stock is computed in the HBD model (Hartman and Rawson 1984), which uses survival rates for life-stage intervals within the facility; these rates may often be derived from past performances at a given facility. In the case of a new stock, they may be derived from experiences with a similar stock. The values of the output variables computed by HBD models are very sensitive to differences in the ocean survival rate, especially if the results are used as input to the FBC model for an economic simulation. The equations for simulating the economic information in the FBC model are found in Appendix B of Hartman and Rawson (1984).

applied as a single value for the 27-year economic life of this analysis (Table 1). It involves five cases, and the cases range from a total harvest of 43.6 million to 101.5 million salmon. A more detailed discussion of the methodology used to develop these estimates is included in Appendix A.

For this analysis, an informed guess of a probability distribution has been assigned to each of the salmon-catch forecasts. An equal probability for cases 2, 3, and 4 occurring (p=0.25), a probability for case 1 (p=0.10), and finally, a probability for case 5 occurring (p=0.15) have been assigned. The basis for the forecast and distribution of probable outcomes are covered in greater detail in Appendix B.

Assumptions of Commercial Fish Harvest Weights for Natural Stock:

Estimates of future fish weights for this analysis have been computed and supplied by the Commercial Fisheries Division (Michael Dean, personal communication). Information for the estimate was taken from a computerized data base (Anonymous 1984). A 5-year average (1979-1983) has been used to estimate mean weight (kg) of fish for all state-wide salmon stocks (Table 2). Since the average weight for each species has a small standard deviation, mean salmon weights are assumed to be a reasonable predictor for estimating the total biomass of the catch for each species on a statewide basis (Peter Leitz, personal communication).

Estimating the Total Revenue (prices) for Commercial Harvests:

This section deals with the demand and price forecasting for commercially harvested Alaskan salmon and is used in calculating benefits for the economic analysis. The task of forecasting prices or changes in total revenue from various management or enhancement schemes can be approached in more than one way.

If complete information were available on consumers, markets, and prices, the analyst might be able to add the *consumer* and *producer surpluses* related to the project. This process would start with a demand function for the final product at the retail level, continue through the intermediate demand stages (e.g., first wholesale level), and finally end at the fishing fleet. Any profits gained (from the harvesters through the consumers) are summed to equal total surplus, which is often referred to as net-social gain. Since a portion of our analysis focuses on an Alaskan accounting perspective, ideally, we would account for all of the components of surplus gained by residents of Alaska. Fortunately for our task, the step of estimating consumer surplus for commercially harvested salmon is unnecessary. This is because almost all of Alaska's domestically harvested salmon are exported. Thus, from a state accounting perspective, Alaskans will not receive consumer surpluses at the retail level.

Some studies on salmon marketing have focused on development of derived demand functions for fish. Derived demand deals with the demand for a good at some intermediate level of production (Allen et al. 1984). One approach for estimating derived, or intermediate, demand would be to estimate total revenue from a wholesale level. Demand functions for estimating the change in total revenue for the Canadian salmon hatchery program are derived from first-level wholesale-price information (Peter Leitz, personal communication). Most of the demand functions designed to forecast salmon prices at the wholesale level suggest that wholesale prices and supply of domestically produced salmon are not the only important variables in the analysis. Other significant variables in the long-term analysis are personal income in national and international market areas, expected population growth, domestic/international exchange rates, and price of substitutes. In the case of the Canadian economic analysis, once the demand function is developed, profits to processors and the fishermen are estimated by subtracting all of the processor and fishing costs (including all opportunity costs).

Demand functions for salmon at the first-wholesale level (where P=f[Q], P = Price, and Q = Quantity) generally have point elasticities that are greater than 1 (Anonymous 1982). An *elasticity* of greater than 1 (unity) indicates that only a small change in the price of a good is necessary to stimulate a substantial change in the quantity of the good that is demanded. Canadian econometrician DeVortz (1983) also notes that for the demand functions developed for the Canadian Salmon Enhancement Program (SEP), demand elasticities over the valid portion of the demand curve are greater than 1. Thus, "it may be expected that as supply increases in the future, any drop in price will yield a growth in revenue" (DeVortz 1983).

Some obstacles exist for application of the first-wholesale level price approach to the Alaskan salmon picture. Verifiable price data for Alaskan salmon at the wholesale level do not exist. Demand analysis at the wholesale level (or any level) requires an historical price series that is adequately disaggregated and fairly precise and one that extends back two or more decades. Since wholesale-price information is supplied from interviews instead of published lists, it is difficult to verify. Cost functions for estimating processing costs for the Alaskan packing industry do not exist. Another limitation is that many processors are owned by firms outside of Alaska; from a state income perspective, this complicates revenue estimates. Finally, the forecasting of prices from first-wholesale level information may simply not be necessary, if Alaskan processors operate in a perfectly competitive market. That is, if increases in salmon output result in the potential for increased *economic rent* to Alaskan packers, then new firms will enter the market and dissipate any additional rent. Thus, after a period of time, profits to processors would approach zero: a break even return. This is of great importance for our process of choosing a methodology for forecasting Alaskan salmon prices. The determination that processors earn small or no profits above a normal rate of return (a break even return) makes the approach of projecting first-wholesale prices for Alaskan salmon a less desirable option. Still, it is possible for some profits (greater than normal) to be made by processors during periods of rapidly increasing salmon harvest. Where this temporary condition exists, we may understate the net benefits of the enhancement projects.

Demand functions for ex-vessel price projections are examined next. Ex-vessel prices refer to the price received by the fishermen at the time of landing or sale of catch. They are the most direct way of estimating the gross revenue from fisheries enhancement.

There are a few alternative means of estimating future ex-vessel prices. One methodology used in the valuation of Alaskan salmon resources assumes that, when evaluating an increment in the fish stock, average prices for several consecutive years will accurately predict the change in gross revenue. Fisheries economists (Crutchfield et al. 1982) have used a 3-year price range to estimate the mean. Their approach assumes that output of salmon (at some defined level in the analysis) will not affect price or that, at least, the effects on price would be small. So, a firm or government would be assuming that they are not in a position to influence market prices by changing the level of output. This is probably a reasonable assumption for a small change in catch; however, in recent history, Alaska's salmon catch has represented a very large portion of the world's salmon supply. Furthermore, the increment we are inspecting in this analysis is on the order of millions of salmon. Under these assumptions, the probability of some price-searching power by the State of Alaska is high enough to justify an econometric demand analysis. Thus, for the purpose of this analysis, the assumption of some *monopoly power* (at the state government level) has been assumed to exist. This has resulted in the creation of a price-forecasting model, which was developed by the CFEC (Muse 1984).

Estimates of future prices have been made using price models based on Muse (1984). Muse conducted the econometric study to specifically address the price-forecasting needs of the Fisheries Mini-Cabinet enhancement evaluation project. The price-forecasting work resulted in nine final price-forecasting equations recommended by Muse and used in this benefit-cost analysis. All of the equations have been developed using linear or semi-log models. Of the numerous model forms and variables that have been tested by Muse, his criteria for the final nine choices were (1) statistical fit and (2) consistency with economic theory. The nine equations consist of linear and semi-log models for pink salmon, chum salmon, coho salmon, and sockeye salmon. A different approach was used for development of a chinook salmon price-forecasting model that consisted of an evaluation of average real prices only; these are expressed in the form of a linear equation.

Of particular importance to the benefit-cost study is the behavior of the two price-forecasting model forms. Both model types have been used to evaluate the enhancement projects in this study. Five of the final price models are based on a linear equation, and four of the final models are based on a semi-log equation. At high-landing levels, the linear model for all species tends to produce lower price estimates than the semi-log form. Conversely, the linear model produces higher price estimates at low levels of harvest.

A full accounting of the five original linear models is available in Muse (1984). A summary of the linear models and 4 additional semi-log models developed by Muse are covered in Appendix F. Further discussion on the limits of econometric price-forecasting models are also included in that appendix.

Forecasts of future ex-vessel prices could be made in other ways, including extrapolations from historical values and educated guesses made by persons familiar with salmon markets. These approaches and the use of models, such as those utilized in this cost-benefit analysis, may all be useful, particularly for comparative purposes.

Estimating the Marginal Cost of Fishing Effort for Commercially Harvested Salmon:

In the preceding discussion, we have accounted for the change in total revenue of the fishing fleet attributable to enhancement production. We will now estimate the total cost of harvesting the enhanced stock for the private sector. The three components that will be discussed are of primary importance in estimating the costs of harvesting the enhancement-produced salmon.

Assumptions of Capital Costs of Salmon Fishing. The Alaskan salmon fleet, and other Pacific salmon-fishing fleets, have been characterized as being largely overcapitalized (Crutchfield and Pontecorvo; Pearse 1982). In short, the balance of literature on this subject points out that salmon fisheries have greatly expanded fishing power in recent years; but because the quantity of fish harvested is essentially determined by factors that are independent from fleet investment (such as annual fluctuations in salmon stock size), new capital investments in vessels, gear, and advanced technology added to the fleets have been largely wasted. In Alaska one consequence of fleet capitalization has been the established ability of the fleet to harvest well beyond the 1978 to 1984 average harvest. The record 1985 harvest (138 million salmon) is considered by fisheries managers to be below the present harvesting capabilities of the Alaskan fleet.

This analysis assumes that the general response of fishermen to increased success from larger salmon harvests will be little or no added reinvestment in fishing capacity. Thus, average cost (total cost) of investment in fleet capacity in the 1984 simulations is not assumed to vary with enhancement-produced catch. Despite this, there is a great deal of agreement between fisheries economists that the current combination of fisheries policies and increased catches will result in a gradual increase in unnecessary fishing power. The anticipated investment is linked to each permit holder's expectation of a larger portion of the catch with a more competitive vessel and gear.

A direct estimate of the rate of fleet capitalization that might result from larger salmon harvests in Alaska does not exist at this time. One applied cost function for a national salmon fishery developed by Canadian Department of Fisheries and Oceans (DFO) economists suggests that fishermen exposed to a voluntary vessel buy-back program would *dissipate all rents* from the program in 5 to 10 years (Peter Leitz, personal communication). This might be a useful base assumption for future project evaluation because, like enhancement projects, vessel or permit buy-back programs are expected to produce an instantaneous jump in gross revenue to the fleet. If fishermen who anticipate increased gross revenue from enhancement behave the same as those exposed to increased gross revenues of the buy-back program, then we can expect a similar rate of capitalization, and thus, rent dissipation. Our assumption of no rise in fixed costs due to enhancement may be optimistic, if the program succeeds in increasing gross revenue to the fleet. Any efforts to increase gross revenues of fishermen by simply increasing catches or by an increase in prices may result in some dissipation of future profits.

It is possible that some techniques to reduce overexpansion of the fishing fleet (often referred to as fleet rationalization and currently under study) could be implemented through legislation. If such techniques were implemented in the next 10 years and were successful, assumptions of low capital costs might be realized.

Assumptions for Variable Costs of Fishing. The variable costs of catching enhancement-produced salmon are primarily the labor resources associated with the increased fishing effort. Other components of fishing effort costs are food, fuel, boat and gear maintenance, bait, and ice. According to Orth (1980) and Muse (1982), estimates for these costs range from 0.0% to 39% of fishermen's gross revenues, respectively.

Small increases (less than 15%) in the harvestable stock of Alaskan salmon will probably result in no perceptible change in variable fishing costs. An increase in the density of the stock in any given net-fishery harvest zone will simply result in a higher catch-per-unit effort, as opposed to longer fishing periods. Larger projected incremental increases in harvesting, which are anticipated during the late 1980's and early 1990's from the enhancement program, are expected to require small additions to total labor. For the purposes of this study, an assumed fraction of 15% of the change in total revenue at the landed-value level will be used for estimating the enhancement-associated variable fishing cost over the 20-year projected life of the program. For the purposes of this analysis, PNP harvest costs are assumed to be equal to fleet costs for enhancement-produced fish.

The preceding section on capital costs discusses the possible consequences of a fishing fleet exposed to immediate increases in profits. If increases in fishing power occur, they may have an effect on variable fishing costs attributable to enhancement, since a more powerful fishing fleet could consume greater energy resources in a given opening. Under such conditions, our estimates of variable costs could be understated.

Assumptions of Social Labor Cost of Commercial Fishing Effort. Since a large component of the variable costs of the fishing fleet is labor, the methods for computing labor costs are important for our analysis. An important distinction for calculation of labor costs is that *total labor cost* estimates should not be confused with *social labor costs*, which are usually developed for efficiency estimates of government investments (Shaffer 1977). "The price paid for labor represents the full social cost of that labor - that is, the amount of other production lost if labor is shifted from some other gainful occupation to fishing" (Crutchfield et al. 1982). Social labor costs would be approximately equal to total costs only in a full-employment economy. If boat owners in the fishing fleets choose to operate in an economically efficient manner, the number of new people entering the labor force because of increased harvests from enhancement can be expected to be small. Also, because of conditions of pervasive unemployment and underemployment in many Alaskan fishing communities, new entrants to the labor force will probably originate from the pool of unemployed. Use of total labor costs in this analysis will result in a small over-estimate of the variable costs of fishing.

Assumptions of Public Costs from State Treasury:

The benefit-cost framework demands an accounting of all public resources foregone in the process of building, operating, and administering the enhancement facilities starting in 1984. Public capital-resource estimates from the state treasury included in this set of simulations are modified from ADF&G annual budget requests and budget forecasts for specific programs in future years of the simulations. Annual operating costs for state-operated hatcheries have been projected from past hatchery-performance data and future salmon-production estimates of the broodstock portion of the simulation program (Hartman and Rawson 1984).

PNP hatchery costs have been estimated from their own data, using the same general criteria as state-operated hatcheries. Much of the operating capital for the PNP hatcheries is expected to come from state loan programs or from assessments of regional fisheries. In this study it is not necessary to differentiate between resources that will originate directly from the state treasury for state-owned facilities, loans to PNP facilities, or from private assessments for PNP facilities. Because of the nature of the below-market interest rate on PNP loans, the long deferred-interest period, and the long life of the loan period, the present value of costs does not change significantly with the funding mechanism.

Essentially, state government is foregoing the use of these funds for the term of the loan period, which is from 15 to 25 years. Additional public resources for state-owned hatcheries have been explicitly dealt with in the analysis. The examples include the cost of biological evaluation and state administrative services; each are assumed to be approximately 15% of the annual operating cost of each enhancement facility. The projection of cost for biological evaluation was estimated from historical information on the state-owned facilities. They are focused on the portion of the evaluation that can be attributed to a specific enhancement project. The administrative costs can be further broken down into divisional administration (2/3) and state administration (1/3). The following list identifies major components of the divisional and statewide administrative costs that are included in the analysis and are attributed to the hatchery program costs in the above constants:

Components of Administrative Costs

FRED Division

1. Planning and Legislation
2. Personnel (administrative)
3. Purchasing
4. Budgeting
5. Management
   -program
   -fish culture
   -genetics
   -pathology
   -personnel
   -biology

State as a Whole

1. Legislation
2. Personnel (administrative at the state level)
3. Purchasing

As discussed in the preceding section, some labor resources for construction and operation of enhancement and rehabilitation facilities will clearly come from unemployed or underemployed ranks. Consequently, total labor costs used for the benefit-cost framework in this analysis are slightly overstated.

Estimating Value of Recreationally Harvested Salmon from Enhancement:

Many of the projects and facilities in FRED Division (some almost entirely) produce salmon and trout highly valued by the state's sport fishery. This section explains the economic methodology and computations used in the Fisheries Mini-Cabinet enhancement evaluation project for valuation of recreational sport fishing. Since several techniques exist to deal with recreational valuation, our choice will depend on the enhancement policy question being addressed. That question focuses on the amount that sport fishermen are willing to pay for additional fish from the enhancement program. The results of this study may not be appropriate to apply to other policy questions.

In order to determine the value of commercially harvested salmon, ex-vessel prices and the change in prices may be estimated by the quantity of fish supplied and other variables. In our valuation methodology, this results in an estimate of the change in total revenue. By subtracting the costs to fishermen for harvesting the salmon, we can determine the net benefits to the commercial fishery. Determining the net benefits of recreational fishing, on the other hand, is a more abstract problem and is often more difficult to quantify; however, it is not possible to address the Governor's policy concerns without completing this step.

The literature that deals with valuation procedures for recreational fishing points out that it is inappropriate to use economic activity as the sole measure of the value of a nonmarket good such as sport fishing. McConnell (1979) states that "in the absence of good information about net social benefits for open access activities, decision makers tend to respond to measures which reflect the total level of economic activity. Decisions based only on the level of economic activity can have rather severe consequences for nonmarket activities such as recreation . . . No economist would argue seriously that fisheries management requires simply the computation of *user cost* and the imposition of a fee per pound of fish landed equal to the user cost." Even so, some decision makers use economic activity (fishing expenditures on travel, boats, and equipment) to directly determine recreational values. Responding to this, economists have proposed the use of direct and indirect methods of measuring changes in welfare in order to achieve an optimal mix of commercial or recreational use. These techniques are also used to determine the efficient level of public investment for publicly provided recreation. The changes in welfare are often referred to as consumer surplus; i.e., the excess of the fisherman's enjoyment over his costs.

To further illustrate this point, some discussion of nonmarket valuation is necessary. In economic-value estimates of the type we are conducting, a "good" does not have to result in an exchange of cash to have value. This concept becomes increasingly important in valuation of air, water, or fish and wildlife resources. Since no formal transaction or exchange of money is taking place between sport fishermen and the suppliers of the fish (in the case of our enhancement projects, this is primarily government itself), it is difficult to track the amount a consumer of sport-fishing recreation is willing to pay for the opportunity to fish for an enhanced stock.

Economists have developed a number of valuation methods for indirectly estimating net willingness to pay for sport fish. Larson (1982) provides a partial review of these valuation techniques. Additional methodological approaches to non-market analysis are available in Talhelm (1984) and Dwyer et al. (1978).

A sport fish valuation study based on estimates of consumer surplus is being conducted by ADF&G (Michael Mills, personal communication). This study, which is in the data collection stages at this time, may provide some useful economic information for enhancement in the future. The work is not sufficiently complete to use in our study at this time. Michael Mills has prepared the following narrative for this study:

> In addition to expenditures actually paid out, sport fishermen also receive other direct benefits from sport fishing. Just as commercial fishermen would be unlikely to continue fishing if their expenses exceeded revenues, sport fishermen would not continue to fish if the enjoyment they derived from fishing did not exceed that which they could get by using their money and time in other ways. Thus, for individuals to continue sport fishing, the value of the experience must exceed their expenditures. This surplus value (consumer surplus or net willingness to pay) is an important part of sport fishing values. Its estimation is often the focus of sport fishing evaluation studies.
>
> Ongoing work by the Sportfish Division is focused on two commonly used methods for estimating nonmarket benefits. One approach is "contingent valuation", and it depends on asking individuals questions that attempt directly to elicit willingness to pay bids . . . [responses to direct willingness to pay questions] . . . The other deduces value measures from observed, related market behavior. This approach relies on the estimation of recreational demand models and in almost all cases it is some form or elaboration of the long used "travel cost" method. The travel cost method uses access costs over various distances from the fishing resource as a proxy to develop demand models.

Beyond the ongoing work of Mills, there is no model that successfully incorporates the quantity of enhancement fish made available for recreational harvest into usable demand functions (equations) for estimating net willingness to pay for sport fishing in Alaska. In the absence of fully developed recreational demand models in Alaska, we have taken a greatly simplified alternative approach. The intent of this approach is to provide at least a minimal amount of information to decision makers interested in valuation of enhancement projects. The two valuation methods that will be presented are intended to bracket the range of sport-fishing values from the enhancement program.

The first valuation option involves estimating a lower boundary for the analysis from the economic rent lost from commercial fishing opportunities. The computation for this value assumes that for each anadromous salmon harvested in the sport fishery, the recreational value is simply the opportunity costs of the commercial fishery. This implies that harvest by the two user groups are mutually exclusive or that salmon not harvested in the commercial fishery would be harvested or at least available to be harvested in the sport fishery. Since the foregone opportunities of commercial fishermen will usually be less than the net willingness to pay for the same stock of fish for the sport fishermen, this will provide an estimate that will clearly undervalue the stock of fish available for recreational harvest.

The second valuation technique was constructed from existing data on catch, effort, value, and abundance. For the purposes of this study, we will call this technique an "effort-based surplus estimate".

Estimation of the variables were based on a review of data bases on existing sport fisheries and enhancement-stocking sites. The catch and effort data used to compute CPUE were produced from existing data from (Mills 1980, 1981, 1982, 1983). The average consumer-surplus estimates in this analysis have been provided by a review of fishing data at or near stocking sites for which the Division of Sport Fish has preliminary travel cost or contingent valuation data. In the real world the *catch rate, CPUE,* and *value per angler day* vary with a number of factors (*see* DISCUSSION). In our analysis, the sites with limited valuation data were estimated separately for each species and fish planting site by extrapolating from sites with similar characteristics and more complete data.

The computation in the following equation (Equation 3) estimates the net benefits to the recreational fishery and has been applied to the planting sites receiving hatchery fish. In some of the planting sites, the abundance (or catch) of salmon and trout to the sport fishery has been forecasted to increase dramatically. Where the increase is estimated to occur, a second level of catch rates (R), CPUE (C), and value per angler day (V) may be estimated for the analysis. A new estimate is made where significant changes in any of the three variables are anticipated to occur.

The computation used for estimating upper-bound value of the enhancement production (effort-based surplus estimate) is:

$$(H\ R/C)V = \text{Net benefits to recreational fishery} \qquad [3]$$

Where:

H = Available Harvest (number of fish)
R = Catch Rate (fraction of catch)
C = CPUE (catch/angler day)
V = Value Per Angler Day ($/day of effort)

Data were collected from representative stocking sites and used to calculate H, R, C, V, and the net benefits for the available harvest. Fish-planting sites not included in the evaluation were lumped into categories of similar composition, in terms of value-per-angler-day, catch rate, and catch-per-unit effort. It should be noted that determination of fish-stocking sites is a year by year event. Sites are frequently changed, based on survival success, fishing effort, and numerous other variables.

Some errors in the analysis will occur if our projection of future planting sites differs much from the actual planting sites.

The state accounting perspective used in the enhancement-evaluation project demands that the net benefits (in our valuation method) of the sport catch be adjusted for the portion of anglers who are residents of Alaska. As explained in the accounting perspective section, the residency of the fishing fleet is used in this study as an approximation of the amount of consumer surplus (or net benefits) remaining in the state. A large portion of the enhancement of anadromous species is aimed at population centers of Alaska that have relatively low access costs. Furthermore, almost all of the landlocked rainbow trout and coho salmon and grayling planting programs are aimed at and accessible to urban fishing populations. Out-of-state fishermen, who spend considerable sums on travel to get to Alaska, rarely participate in the enhanced landlocked fisheries (Michael Mills, personal communication). Therefore, a strong case could be made for assuming that resident fishermen received nearly all the surpluses that accrued to recreational consumers of enhanced stocks. For the purpose of this analysis, the residency fraction weighted for all recreationally harvested stocks from enhancement is assumed to be at 0.9. (Mills 1983), implying that approximately 90% of the net benefits from enhancement of the sport fishery can be applied to the state accounting perspective.

The procedure for the effort-based surplus approach establishes reasonable upper boundaries for the analysis, while the opportunity cost to the commercial-fisheries approach would establish the lower boundaries; thus, with these two cases, it should be possible to provide a rough estimate of the recreationally harvested fish from enhancement.

Caution should be used when comparing these rough estimates of consumer surplus from the recreational-valuation with producer surplus (net benefits for the commercial fishery). The current state of our recreational-valuation method probably does not have enough precision to use for allocation comparisons between competing uses of salmon or policy questions beyond those addressed in this study.

RESULTS

Results of the Commercial Fish Valuation

Tables 3-8 report the results of a portion of the economic analysis. Each table summarizes the benefits and costs of the commercial fishery as well as the private and public costs of constructing and operating the facilities. Included in the tables are the present value of the benefits, costs, net present value (NPV), and the benefit:cost (B:C) of each case in the analysis. Each case (A through F) corresponds to a specific level of salmon catch from the 34 hatcheries in this study. The assumptions that are tested in the analysis and displayed in Tables 3-8 are summarized in Table 9.

A key to the column headings in Tables 3-8 follows: (1) Natural Production is the average Alaskan catch of naturally produced salmon over the life of the program; (2) PV of Profits is the present value of the profits to commercial fishermen, or PV of $B_{pri} - C_{pri}$; (3) PV of Costs is the present value of the public costs from the state treasury, or PV of C_{pub}; (4) NPV is the present value of the net benefits or PV of $B_{pri} - C_{pri} - C_{pub}$; and (5) B/C is the profits of the private sector divided by the costs of the public sector, or PV of $(B_{pri} - C_{pri})/C_{pub}$.

The results demonstrate that there are several sensitive variables in the analysis. Some that have been tested are point estimates from data; others are variables that have been developed from the treatment of data. Among the most sensitive variables are price-forecasting model type (linear vs. semi-log), natural-stock harvest over 20 years, hatchery-fish survival, and commercial-fish catch rate.

Table 3. Assumptions and results for the present values and net present values of the commercial fishery for case A. a/

State Accounting Perspective b/

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	238,687.0	193,001.0	45,686.0	1.24:1
77.2m	165,750.7	193,001.0	-27,250.3	0.86:1
86.3m	66.897.0	193,001.0	-126,104.0	0.35:1
101.1m		not evaluated		

National Accounting Perspective

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	326,968.49	193,001.0	133,967.49	1.69:1
77.2m	226,126.47	193,001.0	33,125.47	1.17:1
86.3m	91,639.0	193,001.0	-101,361.3	0.47:1
101.1m		not evaluated		

a/ The number of hatchery salmon to be harvested (in millions) when the enhanced stock reaches steady-state production in the year 2000: Pink - 13.47; Chum - 5.25; Sockeye - 0.88; Chinook - 1.44; Rainbow - 0.00; Steelhead - 0.00; Coho - 0.64; Grayling - 0.00. Total harvest: 21.04.

b/ Assumptions:

1. Linear Price Model.
2. Commercial fish exploitation rate fixed at 66.6% of total.
3. Excess escapement excluded (pessimistic level catch)
4. Excludes sport fish in present value
5. Commercial costs not subtracted out of benefit side of calculation (optimistic harvest cost scenario)

Table 4. Assumptions and results for the present values and net present values of the commercial fishery for case B. [a/]

State Accounting Perspective [b/]

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	202,883.9	193,001.0	9,882.95	1.05:1
77.2m	140,888.0	193,001.0	-52,112.91	0.73:1
86.3m	56,862.45	193,001.0	-136,138.55	0.29:1
101.1m		not evaluated		

National Accounting Perspective

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	277,923.15	193,001.0	82,922.1	1.44:1
77.2m	192,207.50	193,001.0	-793.5	1.00:1
86.3m	77,893.15	193,001.0	-115,107.46	0.40:1
101.1m		not evaluated		

a/ The number of hatchery salmon to be harvested (in millions) when the enhanced stock reaches steady-state production in the year 2000: Pink - 13.47; Chum - 5.25; Sockeye - 0.88; Chinook - 1.44; Rainbow - 0.00; Steelhead - 0.00; Coho - 0.64; Grayling - 0.00. Total harvest: 21.04.

b/ Assumptions:
1. Linear Price Model.
2. Commercial fish exploitation rate fixed at 66.6% of total.
3. Excess escapement excluded (pessimistic level catch)
4. Excludes sport fish in present value
5. Commercial costs subtracted out of benefit side of calculation (pessimistic harvest cost scenario)

Table 5. Assumptions and results for the present values and net present values of the commercial fishery for case C. [a]

State Accounting Perspective [b]

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m	649, 219.5	193,001.0	456,218.5	3.36:1
66.2m	295,081.4	193,001.0	102,079.8	1.53:1
77.2m	154,557.9	193,001.0	-38,443.1	0.80:1
86.3m	16,978.1	193,001.0	-176,022.9	0.09:1
101.1m	-138,119.4	193,001.0	-331,120.4	0.71:1

National Accounting Perspective

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m	869,102.0	193,001.0	676,101.4	4.5:1
66.2m	394,855.9	193,001.0	201,854.0	2.05:1
77.2m	206,904.8	193,001.0	13,903.8	1.07:1
86.3m	23,257.67	193,001.0	-169,743.3	0.12:1
101.1m	-138,119.4	193,001.0	-331,120.4	0.71.1

a/ The number of hatchery salmon to be harvested (in millions) when the enhanced stock reaches steady-state production in the year 2000: Pink - 19.04; Chum - 7.37; Sockeye - 1.17; Chinook - 0.19; Rainbow - 0.00; Steelhead - 0.00; Coho - 0.86; Grayling - 0.00. Total harvest: 28.63.

b/ Assumptions:
1. Linear Price Model.
2. Commercial fish exploitation rate (varies).
3. Excess escapement included (optimistic level catch)
4. Excludes sport fish in present value
5. Commercial costs not subtracted out of benefit side of calculation (optimistic harvest cost scenario)

Table 6. Assumptions and results for the present values and net present values of the commercial fishery for case D. [a/]

State Accounting Perspective [b/]

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	537,797.9	193,001.0	344,796.9	2.79:1
77.2m		not evaluated		
86.3m	469,737.9	193,001.0	267,736.9	2.43:1
101.1m	203,406.0	193,001.0	10,405.0	1.05:1

National Accounting Perspective

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	736,709.4	193,001.0	543,708.4	3.82:1
77.2m		not evaluated		
86.3m	626,203.0	193,001.0	433,202.0	3.24:1
101.1m	341,515.1	193,001.0	148,514.1	1.77:1

a/ The number of hatchery salmon to be harvested (in millions) when the enhanced stock reaches steady-state production in the year 2000: Pink - 19.04; Chum - 7.37; Sockeye - 1.17; Chinook - 0.19; Rainbow - 0.00; Steelhead - 0.00; Coho - 0.86; Grayling - 0.00. Total harvest: 28.63.

b/ Assumptions:
1. Semi-Log Price Model.
2. Commercial fish exploitation rate (varies).
3. Excess escapement included (optimistic level catch)
4. Excludes sport fish in present value
5. Commercial costs not subtracted out of benefit side of calculation (pessimistic harvest cost scenario)

Table 7. Assumptions and results for the present values and net present values of the commercial fishery for case E. [a/]

State Accounting Perspective [b/]

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	632,703.4	193,001.0	439,702.4	3.28:1
77.2m		not evaluated		
86.3m	522,632.9	193,001.0	329,631.9	2.71:1
101.1m	293,301.2	193,001.0	100,300.2	1.52:1

National Accounting Perspective

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m		not evaluated		
66.2m	866,717.0	193,001.0	673,715.0	4.49:1
77.2m		not evaluated		
86.3m	715,935.5	193,001.0	522,934.5	3.71:1
101.1m	401,782.5	193,001.0	208,781.5	2.08:1

a/ The number of hatchery salmon to be harvested (in millions) when the enhanced stock reaches steady-state production in the year 2000: Pink - 19.04; Chum - 7.37; Sockeye - 1.17; Chinook - 0.19; Rainbow - 0.00; Steelhead - 0.00; Coho - 0.86; Grayling - 0.00. Total harvest: 28.63.

b/ Assumptions:
1. Semi-Log Price Model.
2. Commercial fish exploitation rate (varies).
3. Excess escapement included (optimistic level catch)
4. Excludes sport fish in present value
5. Commercial costs not subtracted out of benefit side of calculation (optimistic harvest cost scenario)

Table 8. Assumptions and results for the present values and net present values of the commercial fishery for case F. a/

State Accounting Perspective b/

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m	551,836.6	193,001.0	358,835.6	2.86:1
66.2m	250,819.9	193,001.0	57,817.6	1.30:1
77.2m	131,374.2	193,001.0	-61,626.8	0.68:1
86.3m	14,431.4	193,001.0	-178,569.6	0.07:1
101.1m	-100,000.0	193,001.0	-293,001.0	N/A c/

National Accounting Perspective

Natural harvest of salmon	PV of profits $1000s	PV of costs $1000s	NPV $1000s	B/C
43.5m	738,736.7	193,001.0	545,735.7	3.38:1
66.2m	335,627.5	193,001.0	142,625.9	1.74:1
77.2m	175,869.1	193,001.0	-17,131.9	0.91:1
86.3m	19,769.0	193,001.0	-173,231.0	0.10:1
101.1m	-100,500.0	193,001.0	293,501.0	N/A c/

a/ The number of hatchery salmon to be harvested (in millions) when the enhanced stock reaches steady-state production in the year 2000: Pink - 19.04; Chum - 7.37; Sockeye - 1.17; Chinook - 0.19; Rainbow - 0.00; Steelhead - 0.00; Coho - 0.86; Grayling - 0.00. Total harvest: 28.63.

b/ Assumptions:
1. Linear Price Model.
2. Commercial fish exploitation rate (varies).
3. Excess escapement included (optimistic level catch)
4. Excludes sport fish in present value
5. Commercial costs subtracted out of benefit side of calculation (pessimistic harvest cost scenario)

c/ Note that when the numerator (benefit side of the fraction) is negative, it is impossible to calculate a benefit-cost ratio. Also, it is impossible to determine the difference between the national and state accounting stance.

Table 9. Listing of variables tested in commercial fisheries analysis for Tables 3 through 8.

Variable	Case A	B	C	D	E	F
Accounting perspective (national)	X	X	X	X	X	X
Accounting perspective (state)	X	X	X	X	X	X
Price model type (linear)	X	X	X	O	O	X
Price model type (semi-log)	O	O	O	X	X	O
Exploitation rate (fixed)	X	X	O	O	O	O
Exploitation rate (variable)	O	O	X	X	X	X
Excess escapement (included)	O	O	X	X	X	X
Excess escapement (not included)	X	X	O	0	O	O
Harvest costs (subtracted)	O	X	O	X	O	X
Harvest costs (not subtracted)	X	O	O	O	X	O
Natural harvest (43.5 million)	O	O	X	O	O	X
Natural harvest (66.2 million)	X	X	X	X	X	X
Natural harvest (77.2 million)	X	X	X	O	O	X
Natural harvest (86.3 million)	X	X	X	X	X	X
Natural harvest (101.1 million)	X	X	X	X	X	X

The present value of the profits from the fishing fleet suggest that if harvests of the natural-stock catch remain at 66-86 million salmon for 20 years, the economic profits to fishermen will range from *normal* to well above normal, depending on price-forecasting model type (Table 10). From the perspective of the private sector, normal profits mean that the investment is breaking even (economic profits of approximately zero or B/C ration of 1:1).

The present value of the net benefits from the results suggests that if natural-stock catch rates remain at 66 to 86 million for 20 years, the net benefit to Alaska will range from below zero to well above zero (Table 10). The midpoint of the NPV ($96.5 million) from the most likely cases is slightly above a breakeven return. The B/C ratio of the midpoint is 1.43:1. The variability in this outcome is also heavily influenced by the price-forecasting model type.

If catch rates for the natural stock are in the range of 101 million salmon, profits to the fishing fleet will be slightly below normal and the NPV will be well below zero when estimated with the linear model and only slightly above zero when estimated with the semi-log model. If the catch for the natural stock falls to an average of 45 million salmon, then the profits to the fishing fleet (PV of Profits) will be significantly above normal with either price-forecasting model. The NPV will also be positive for the 45 million case with both price-forecasting models.

When evaluating the boundaries tested on the linear-price model, the assumptions involving the harvest of the naturally produced stock are highly sensitive to the analysis. For example, the NPV for the 66.2 million case, the linear model, state-accounting perspective, varying hatchery-exploitation rates (optimal hatchery exploitation rates), and optimistic harvest cost (case C) is $102.1 million. The NPV for the 101.1 million harvest case with the linear-price model, variable exploitation rate, and

Table 10. Summary of the present value of profits, NPV, and B/C ratio for cases F and D. Including: natural stock harvest level of 66.2 million and 86.3 million fish, linear and semi-log price models, variable harvest between 67% and 95%, and pessimistic harvest costs of 15% of the total revenue.

Natural Stock Harvest	66.2 million salmon	86.3 million salmon
Linear model		
PV of Profits	$250.8 million	$14.4 million
NPV	$57.8 million	$-178.6 million
B/C (ratio)	1.3:1	0.07:1
Semi-Log model		
PV of Profits	$537.8 million	$469.7million
NPV	$344.8 million	$267.7million
B/C (ratio)	2.8:1	2.4:1

optimistic harvest cost (case C) is $-331.1 million. This is a difference of $433.2 million. When applied to the semi-log model, the NPV of the analysis is not as sensitive to the natural-stock harvest. The NPV for the semi-log model with the same conditions are $439.7 million and $100.3 million, respectively; this is a difference of $339.4 million.

In the linear model, the total revenue to the commercial fishermen increases with the catch until a harvest of approximately 100 million salmon is reached; at quantities above 100 million salmon, the total revenue begins to decrease. In the semi-log model, the total revenue increases until a commercial catch of well over 130 million salmon is reached. It is only after the catch is greater than approximately 140 million salmon that the total revenue begins to decrease.

The two levels of hatchery exploitation examined in this study result in considerably different harvests for enhancement-produced fish in the commercial fishery. The fixed exploitation rate of 67% results in a commercial catch of 21.04 million hatchery fish at the steady-state maximum, which occurs in year 2000. The varying exploitation rate, ranging from between 67% to 95%, has a steady-state maximum of 28.5 million fish, which occurs in the year 2000.

The hatchery exploitation rate is only a moderately sensitive variable in the economic analysis. It (the varying exploitation rate vs. fixed exploitation rate) produces less of a change in the NPV than the varying of the natural stock harvest between any two of the five natural production cases tested. For example, when the fixed exploitation rate is applied to the 66.2 million case, the optimistic harvest-cost scenario, and the linear-price model (case A), it results in a NPV of $45.69 million. For the variable exploitation rate, the linear-price model, the optimistic harvest-cost scenario, and the 66.2 million case (case C), the NPV is $102.08 million. This is a difference of $56.39 million. In contrast, when case A, at 66.2 million (a NPV of

$45.69 million), is compared with the next natural-stock harvest level of 77 million fish (with a NPV of -27.25 million), the difference in the NPV is greater, or $72.94 million.

The reason that the exploitation rate of hatchery fish is not quite as sensitive a variable in an analysis as varying the five levels of natural-stock harvest is because it only results in a small change in total harvest in the commercial fishery, while a change in the natural-stock harvest level would result in a significant change in total harvest. The price-forecasting models are highly sensitive to total salmon harvest. The change in total harvest is small (about 8 million fish) because of varying exploitation rates. In contrast, the change due to varying the level of natural-stock harvest between any two of the five catch levels of natural fish tested is about 10 million or more fish.

This identical set of cases has not been simulated with the semi-log model. Since the behavior of the semi-log model is similar to the linear model because it is sensitive to a total Alaskan harvest, the exploitation assumptions tested in this study will result in a smaller change in NPV than will comparing the 5 catch cases. Thus, the exploitation rate is only a moderately sensitive variable in the semi-log model.

Results of the Sportfish Valuation:

As in our computation of commercially harvested salmon, the sport harvests of salmon and trout from hatcheries are projected to increase gradually from present levels to much higher levels by the year 2,000. The year 2,000 represents the steady state maximum for harvests of each species from enhancement of 468,600 fish (Table 11).

Table 11. Number of sport fish harvested by the year 2,000 from the enhancement program.

Species	number of fish harvested	
Pink	33,300	
Chum	500	
Sockeye	12,000	
Coho	115,500	a/
Chinook	33,600	
Rainbow	216,600	
Steelhead	800	
Other	56,300	b/
TOTAL	468,600	

a/ Includes anadromous and landlocked coho.

b/ Includes catch for sheefish, and grayling harvests.

I have attempted to isolate the component of state-government program costs allocated to the sport and commercial portions of the enhancement production. Program costs are defined in the preceding section: *Assumptions of Public Costs from State Treasury*. The procedure allows for a rough NPV to be estimated for the sport-fishery portion of the statewide enhancement program and a separate one for the commercial portion of the program. The point estimate for the "effort-based surplus estimate" used for determining the profits from the sport fishery results in a NPV that is above zero (well above break even). The present value of the sport benefits in the study for the effort-based estimation method is approximately $362 million. The second sport-valuation method (the opportunity cost of the commercial fishery) varied with the assumptions tested. Using the semi-log method model (86.2 million natural-stock harvest level and 67% harvest rate), the NPV was approximately $25.2 million. This probably represents a lower bound than the NPV of the sport fish enhancement. The present value of the public costs attributable to the sport fish enhancement was approximately $45.6 million. Thus, the NPV of the effort-based consumer-surplus method was $316.4 million, and the NPV of the opportunity-cost method was approximately -$20.4 million. In short, the computations for the two sport-fishing methods were made by determining the difference between the benefits to sport fishermen (from the consumer surplus for method 1 and opportunity cost from method 2) and all government costs associated with enhancement as follows:

PV of Benefits - PV of Costs = NPV

Method 1: $362 million - $45.6 million = $316.4 million

Method 2: $25.2 million - $45.6 million = -$20.4 million

The procedures used in separating the sport from commercial catch are useful for our economic analysis because they allow us to estimate the relative NPV of these two components of the hatchery program. The step of separating the commercial and sport components may leave the mistaken impression that allocation patterns between the sport and commercial fishery can be changed easily. Changing an existing allocation pattern often requires significant changes in management regulations. Such allocation issues are not the subject of this study.

DISCUSSION

My response to the Governor's original policy directive questioned the purpose of this evaluation project: "At a conservative level of investment, would the state generally expect positive net economic benefits from existing and proposed state and PNP projects from a state accounting perspective?" The results that have been presented provide a qualified answer to this question.

Implications of Results for Commercial Fishery Analysis

The commercial-fishing portion of the enhancement study focuses on the present value of the profits to the commercial fishermen and the NPV to Alaska. The cases that we have characterized as "most likely" generally produce normal-to-above-normal profits (pv of profits). In fact, a positive change in total revenue (and pv of profits) is produced in all but the highest (101.1 million) natural-stock harvest case. This suggests that below-normal profits from the enhancement program will probably not occur as long as the fishing fleet operates in an efficient manner (does not invest in greater fishing capacity than required to harvest the total catch).

The present value of the net benefits to the commercial fishery (including the public costs) for the "most likely" cases range from slightly negative to well above a break-even point. The majority of the cases tested between the 66.2 million and 88.3 million levels imply that fishermen who catch the enhancement-produced fish would be willing to bear the public costs of the enhancement projects. This would be the case if the implementation of such a program was possible and had no costs. The midpoint of the NPV and B/C ratios for the most likely cases from Table 10 are $95.5 million and 1.43:1, respectively. While this is an encouraging computation, there are severe problems with making a single-point estimate for an analysis such as this. The reader should view the NPV of the "most likely" cases in the form of a range from $-178.6 million to $344.8 million.

When weighed against the public costs of the program, a few of the NPVs from the linear model (88.3 million and 101.1 million natural-stock harvest cases) are negative. For the cases that forecast a negative NPV, the fishing fleet as a whole would not be willing to bear all the public costs of the hatchery program. In these cases some government subsidy would occur over the life of the investments.

While the present value of the profits to the commercial fishery is positive in the "most likely" cases of this study, there is a large range between the commercial fishery NPVs of the linear and semi-log models for the same cases. It is large enough that we cannot tell precisely whether the program is just above or below a break-even NPV with the "most likely" case assumptions. It is of great importance to the original policy question for the results to indicate that investments are neither severely above or severely below a NPV of zero. A slightly positive NPV for the midpoint of the study leads me to a cautious projection that the commercial portion of the analysis should be considered a break-even investment.

It is not the purpose of this analysis (or benefit-cost analysis in general) to draw *normative* conclusions about whether a government investment should or should not go forward. However, the results of the commercial-fishery portion of the work would suggest that it is not an efficient action, from the standpoint of net benefits, to discontinue the investment in the enhancement program. Conversely, our analysis (specifically, the price-forecasting models) demonstrates that it is probably not an efficient action to radically increase investment in salmon enhancement to twice the size of the predicted program by the year 2000.

As previously discussed, the data from this study are not intended for the ranking of specific facilities. The computations for the model do give us some idea of the relative variability in the present value of the profits and NPV of individual hatcheries. The results indicate a high degree of variability between projects. From an efficiency standpoint, it is expected that further analysis will show that some projects produce high positive NPV and others produce negative NPV. With further evaluation it should be possible to rank projects or identify how borderline projects might be made to be more efficient.

Implications of Results for Sport Fishery Analysis

Our two estimates of present value for enhancement benefits to the sport fishery are more than an order of magnitude apart (PV = $25.2 million and PV = $362 million). It is encouraging that the midpoint of these two values (PV = 193.6) is greater than the present value of the costs of the program attributable to the sport-fishing enhancement ($45.6 million). While the present value of the benefits are probably equal to/or greater than the present value of the costs for the current program, the two values reflect our current uncertainty over the amount of consumer surplus generated to sport fishermen from enhancement. Caution should be used when comparing these rough estimates of consumer surplus from the recreational valuation with producer surplus estimated for the commercial fishery. The current state of our recreational-valuation method probably does not have enough precision to be used for potential allocation comparisons.

Sources of Error in the Effort-Based Recreational Valuation Method:

More elaborate demand functions are available for estimating consumer surplus from recreational fishing. The variables in these techniques are often interactive. Additional explanatory variables that can affect consumer surplus are included in the following list:

1. Abundance of fish in harvest zone (estuary, stream or lake)
2. Quality of fish (size, ripeness)
3. Density of fish in harvest zone
4. Environmental factors
5. Income of participating population
6. Rate of change in population
7. Cost of access
8. Cost of substitutes

Our effort-based valuation methodology formally assumes that total effort (HR/C) will vary directly with the catch; however, the total effort and value per angler day can also change with the abundance of the stock in the fishing zone. If a bag limit or other management strategy is imposed, an increase in effort in the harvest zone can occur without increases in catch. A valuation model based only on catch may understate consumer surplus.

The abundance of anadromous fish available to sport fishermen is directly affected by what escapes the commercial fishery. Our generalized model applies a fixed commercial catch rate to the harvest of hatchery fish that may, in some cases, be larger or smaller than the true catch. Where this occurs, the abundance of fish available to the sport fishery may vary from the model's estimation. This may create some errors in our analysis. For example, some stocks of anadromous salmon may be subjected to a much higher degree of exploitation in the sport fishery than assumed in our analysis.

The literature establishes that an open-access commercial fishery can quickly dissipate the net benefits from an increase in catch (Crutchfield and Pontecorvo 1969). This occurs when the participants freely enter the fishery. Since the sport fishery operates on an open-access basis, consumer surplus (net benefit) can also be dissipated if new fishermen decide to enter the fishery (Anderson 1984). The dissipation of the consumer surplus from competition probably occurs gradually over a number of years. Considerable net benefits can be expected to accrue to fishermen, even if expenditures eventually dissipate all rent.

The rate at which new fishermen enter a fishery is an important variable in the calculation of net benefits to the enhancement program. To a great extent, how the fishery is managed determines the rate of entry as well as the rate of dissipation of net benefits. In the current analysis, the future costs of the sport fishery due to this factor are not estimated. If these are significant costs, our effort-based consumer-surplus calculation will be overstated.

General Limits of the Overall Economic Evaluation

In terms of application to various public-policy questions, the information gained from the results of a benefit-cost analysis can enjoy a great breadth. Our analysis, out of necessity, has been focused on a vary narrow policy question. The primary applications and limits of the data produced from this benefit-cost analysis follow.

The economic model, which is modified for this analysis, and its associated assumptions is capable of being used to identify the value of the existing enhancement program in aggregate. Some limits to applying the current analysis to site-specific enhancement questions exist. Given several assumptions in the structure of this model, it is impossible to focus on the production output of individual hatcheries. This is because price forecasting lumps together species so that it is impossible to differentiate between a management area or hatchery.

Furthermore, the method of sport-fish valuation does not allow for a disaggregation of benefits at the hatchery level, because data are lumped together for a series of release sites. As stated in a preceding section of this study, benefit-cost analysis uses the construction of a with-investment/without-investment analysis; the computations made in the computer program accomplish this by estimating the net benefits to commercial fishermen with and without the investment and then determining if the difference is positive or negative. The difference between the two is reported in the RESULTS section. To investigate individual hatchery-efficiency scenarios, the analyst would be required to simulate with-investment and without-investment schemes for each individual hatchery. While this is a feasible task, it is beyond the scope of this project.

There are, of course, certain limitations to the benefit-cost analysis itself; namely, it is often difficult to put a quantitative value on quality of life or religious values. Furthermore, it is not possible to say much about the distributional effects of specific enhancement projects or policies in the present work. The methodology for dealing with distributional effects is discussed in more detail in the Bio-Economic Analysis section.

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GLOSSARY

1. accounting costs (*see also* user costs)

Costs which involve money (Capital) spent in a transaction. They do not include opportunity costs such as time or lost opportunities.

2. available harvest

The number of fish escaping the commercial fishery that are available to the sport fishery during an open fishing period.

3. catch rate

The sport-fish catch rate is a portion (fraction) of the total enhancement production for a species of salmon or trout that is available to the sport fishery. It is applied to each site anticipating hatchery returns to the sport fishery.

4. catch-per-unit effort (CPUE)

The catch-per-unit effort represents the number of fish that end up in the creels of the fishermen for a day of fishing effort.

5. consumer surplus (*see* producer surplus)

The difference between the maximal total amount a consumer would be willing to pay to have a quantity of a given good, rather than do without it entirely, and the actual total amount he pays for that quantity. Also, it is the triangular shaped piece (delta symbol) above the price line on the demand curve (*see also* demand curve).

6. <u>cost stream, income stream, or revenue stream</u>

A time series of benefits or costs; reoccurring benefits or costs that take place over a long time period; a series of dollar amounts extending into the past or future for a specific number of years.

7. <u>change in total revenue</u>

The difference between the total revenue of the commercial fishing fleet with enhancement and without enhancement. Where total revenue is determined by the price per pound of harvested fish times the quantity of salmon harvested. In mathematical notation it is $Q_2 (P_2) - Q_1 (P_1)$.

Where Q_1 equals the quantity of salmon harvested without enhancement, Q_2 equals the quantity of salmon harvested with enhancement, P_1 equals the price per pound paid for Q_1 salmon, and P_2 equals the price per pound paid for Q_2 salmon.

8. <u>demand curve</u> (demand function)

The mathematical function or graphic curve that illustrates the relationship between the price and quantity of a good. Quantity is normally on the "x" axis and price is on the "y" axis.

9. <u>discount rate</u>

The interest rate (r) used in calculating present value. In the case of a single future amount coming in t years, the discount factor is

$$(1 + r)^{-t}$$

10. <u>dissipation of rent</u> (rent dissipation)

The reduction of profits from increased (and often unnecessary) costs. In a fishing fleet this occurs from unnecessary investment in fishing power to augment the ability of individual fishermen to compete for available fish.

11. economic profit or economic rent

Over a defined time period, the difference between the total benefits and total cost at one quantity of production.

12. efficiency

Maximal production for a given quantity of input or cost minimization for a given level of output (*see also* pareto-efficiency).

13. elasticity or elasticity of demand

The percent change in quantity of a good divided by the percent change in price (%ΔQ/%ΔP). The elasticity of demand can be determined for any point on a demand curve where all other variables are held constant. An elasticity of 1 is called unit elasticity. An elasticity of greater than 1 indicates that only a small change in the price of a good is necessary to stimulate a substantial change in the quantity of the good that is demanded.

14. equity

Distribution of wealth geographically or in different sectors of the economy. It may refer to direct or induced impacts of an investment or action.

15. existence value

Net willingness to pay for the knowledge that some resource of value exists, even if the consumer never has the option of consuming the good. An example would be the value of knowing that a viable population of blue whales will exist into the year 2000.

16. <u>exploitation</u>

The process of reducing a population of fish through fishing. It can include either commercial, sport, or subsistence fishing.

17. <u>external effects</u>

Where a market transaction between two or more people imposes benefits or costs on a third party. Air and water pollution and fisheries are classical areas of external effects.

18. <u>good</u>

A good is something that an individual wants some of, rather than something to do without entirely. The consumer will be willing to forgo some units of something else of value to attain the good.

19. <u>model</u>

A simplified representation of some process. It is simplified because it is put together by ignoring some features of the process and concentrating on a few of the most relevant features.

20. <u>monopoly power</u> (oligopsony power)

The ability of a firm (in a market where sellers are few) to control price through adjustments of the firm's production. The firm may use price control as a weapon in discouraging entry of other firms into the market place. Firms in the salmon processing industry may exercise some oligopsony power.

21. <u>natural stock</u>

A stock of fish that has never been enhanced or rehabilitated by artificial propagation; e.g., fish hatcheries or stream-side incubation facilities.

22. <u>net benefits</u> (net social gain)

Total benefits (revenue) less total costs. In the social context it is equivalent to the consumer surplus plus the producer surplus.

23. <u>nominal interest rate</u>

Nominal interest rates are published interests rates at which people or lending institutions may borrow or lend. For the borrower, the nominal interest rate is the amount paid (per dollar, per year) for the right to borrow money. Future projections of nominal interest rates reflect the real rate of interest plus the expected rate of inflation.

24. <u>normal profits</u> (normal economic profits)

Benefits of the private sector less costs of the private sector, where benefits and costs include all opportunity benefits and opportunity costs. In this report, normal profits to the commercial fishery are where the present value of the fishermen's profits equal zero.

25. <u>normative and positive statements, conclusions, and analyses</u>

A normative statement is one that is based,in part, on opinion. A normative statement cannot be shown to be true or false; e.g.,"the price of sockeye salmon fell by too much in the 1982-1983 season." This statement cannot be tested for accuracy since "too much" is mere opinion. A positive statement can be tested because it is based on what has been or what will be; e.g., "from year 1973 to year 1974 pink salmon prices rose 3 cents per pound in Prince William Sound."

In general, our method of economic analysis is an exercise in positive analysis; however, the very nature of the method of analysis used in this report implies some value judgments on what is useful and important; so our positive method of analysis includes some normative elements.

26. option value

Net willingness to pay for the option to consume a resource of value in the future. An example would be the value (for a potential first visitor to Alaska) of the option to view a herd of caribou in Northern Alaska.

27. opportunity cost

The most highly valued opportunity foregone when an investment action is taken. The opportunity foregone involves any use of time resources or resources of value.

28. pareto-improvement (pareto-efficiency)

Efficiency related to a society. It includes the cost of returning losers in a transaction to their former level of welfare by forcing winners to pay for the redistribution of wealth. Applications can be global, national, or regional.

29. present value

The amount which a person would be willing to pay today to obtain the right to a certain amount or series of amounts in the future as estimated through use of a discount rate. The present value can be determined for a series of benefits or a series of costs.

30. present value of the net benefits

Total present and future benefits less total present and future costs of a project or action discounted to today's dollars with an appropriate interest rate.

31. <u>producer surplus</u> (*see* consumer surplus)

The difference between the maximal total amount a producer would be willing to accept for a quantity of his product to be sold and the actual total amount he receives for that quantity of product. Also, it is the triangular-shaped piece (delta symbol) below the price line and above the supply line on the demand curve.

32. <u>social labor costs</u> (*see also* total labor costs)

Difference between the price (total wages) actually paid for labor and the price (total wages) the labor force would be willing to accept in its next-best employment opportunity.

33. <u>total labor costs</u>

Total wages paid to a specific work force (such as the salmon fishing fleet or employees of the FRED Division).

34. <u>user costs</u>

Accounting costs incurred by a consumer in the process of making a transaction. In the case of sport fishermen, accounting costs would be the total out-of-pocket expenses used during a unit of time in the process of pursuing sport-fishing opportunities. It does not include opportunity costs.

35. <u>value per angler day</u>

This variable is an estimate of the net willingness to pay or the consumer surplus from a day of angling.

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Dean, Michael, Fishery Biologist, ADF&G, Commercial Fish Division, Juneau, AK 99801.

Eggers, Douglas, Chief Biometrician, ADF&G, Commercial Fish Division, Juneau, AK 99801

Leitz, Peter, Economist, Department of Fisheries and Oceans, 1090 West Pender St., Vancouver, BC V6E 2P1

Mills, Michael, Biometrician III, ADF&G, Sport Fish Division, Anchorage, AK 99502

Rhode, Jim, Research and Liaison, Trustees of the Alaska Permanent Fund, 601 W 5th Ave. Suite 435, Anchorage, AK 99501.

APPENDICES

Appendix A

List of Hatcheries and Projects Included in This Analysis

1. Beaver Falls Hatchery
2. Big Lake Hatchery
3. Burnett Inlet Hatchery
4. Burrow Creek Hatchery
5. Cannery Cr. Hatchery
6. Crystal Lake Hatchery
7. Deer Mountain Hatchery
8. Eklutna Hatchery
9. Elmendorf Hatchery
10. Esther Lake Hatchery
11. Ft. Richardson Hatchery
12. Gulkana Hatchery
13. Gunnuk Creek Hatchery
14. Hidden Falls Hatchery
15. Karluk Hatchery
16. Kasilof Hatchery (Crooked Creek Hatchery)
17. Kitoi Hatchery
18. Klawock Hatchery
19. Kowee Creek Hatchery
20. Main Bay Hatchery
21. Medvejie Creek Hatchery
22. Meyers Chuck Hatchery
23. Neets Bay Hatchery
24. Perry Island
25. Port Armstrong Hatchery
26. Port San Juan Hatchery
27. Russell Creek Hatchery
28. Sandy Bay Hatchery
29. Sheep Creek Hatchery
30. Sheldon Jackson Hatchery
31. Sikusuilaq Hatchery
32. Snettisham Hatchery
33. Solomon Gulch Hatchery
34. Trail Lakes Hatchery
35. Tutka Hatchery

Appendix B

Assumptions Regarding Forecasts of Commercial Fishery Yield of Natural Salmon Stocks

A major challenge of applying economic theory to salmon fishery investment decisions is in the forecasting of very sensitive biological variables that involve great uncertainty. For example, one of the sensitive variables for the enhancement evaluation is the expected natural-stock harvest of salmon over the next 20 to 30 years.

Seibel (1984) lists some key variables involved in forecasting the abundance of natural stocks in Alaska. They include consideration of natural environmental conditions, including the probability of major natural catastrophes, such as the 1964 Good Friday earthquake or weather changes. The major human-related variables were user exploitation, fleet management, pollution, and habitat changes.

Seibel (1984) states:

> "In view of the difficulties and uncertainties associated with forecasting long term salmon abundance, it does not seem reasonable or even appropriate to attempt, at this point, to develop a single point estimate. It seems more appropriate to develop a forecast range based on some alternative analytic approaches. The resulting range will in itself provide some measure of the uncertainty associated with the predictions. Conducting B/C analysis with different levels of predicted future salmon production corresponding to lower and upper ends of the range plus some intermediate values may provide additional insight into the effects of future salmon production on B/C (Net Present Values) of hatchery investments"

A very thorough predictive stock-harvest model might identify specific variables that inject uncertainty into the forecast. It could then assign a probability distribution to the variables that would be expressed in a model predicting the distribution of probable future harvests over the decision-time horizon (about 25 years in our analysis).

For the Mini-Cabinet assignment, three methods of stock harvest estimates were used. Each methodology focused on producing a "point estimate" for harvests. From these four primary estimates, a range of probable cases to test in the economic simulation model were constructed:

1. Minimal catch from 5-, 10-, and 20-year moving averages (Rawson and Hartman 1984).

2. Average catch from an analysis of 5-, 10-, and 20-year moving averages. (Rawson and Hartman 1984).

3. Trend analysis of commercial catch from some past year to present (Seibel 1984).

4. Maximal four-generation moving average (Frohne 1984; Douglas Eggars, personal communication).

The authors of the first case focused their forecast on the estimation of a minimal point estimate for the economic analysis by evaluating catches from the early 1920s to 1983. The low point for the 20-year floating average (43.6 million salmon) was chosen as a minimal point for the analysis. The authors of the second case projected a "most likely" catch for the economic analysis. For this approach, the same procedure was used as in the first case, which consisted of a point estimate of average catches from 5-, 10-, and 20-year moving averages. The average point of the 20-year moving average resulted in a catch of 66.2 million salmon.

The author of the third case also developed a forecast for a "most likely" estimate of catches over the time horizon of the projected analysis (1983 to 2004). This approach was a trend analysis of recent catches. The point estimate for the trend was 88 million. It also determines an upper bound for the trend of about 120 million salmon.

The author of the maximal four-generation moving-average method (Case 4) approached the problem from the standpoint of estimating an optimistic single-point average. This was accomplished by identifying the maximal point of the four-generation moving average, resulting in an estimate of harvests of about 101 million salmon.

Much debate is possible over the probability distribution of the different stock-harvest estimates provided in these approaches. After review of the methodologies, the staff of the mini-cabinet decided to evaluate several alternative catch levels in the simulation model and assign a probability distribution to the points evaluated. The alternative catch levels chosen for the analysis were 43.6 million salmon (p= 0.10), 66.2 million salmon (p =0.25), 77.3 million salmon (p=0.25), 86.3 million salmon (p=0.25), and 101.5 million salmon (p=0.15). The corresponding catch by a given species is listed in Table B-1 (reprinted from the text).

Table B-1. An estimate of natural-stock yield in millions of salmon by species and case.

Case	Pink	Chum	Sockeye	Coho	Chinook	Total
1.	25.0	4.7	11.7	1.6	0.4	43.6
2.	37.9	7.1	17.7	2.4	0.7	66.2
3.	44.3	8.3	20.7	2.8	0.8	77.3
4.	49.5	9.3	23.1	3.1	0.9	86.3
5.[a]	62.9	8.1	25.4	2.9	0.76	101.5

[a] Note: Projected harvests by species (for case 1 through 4) have been computed by taking the arithmetic mean of the catch apportionment for each of the five species over the last twenty years of salmon catches. During years of higher harvests the apportionments of coho and chinook catches consistently vary downward from the means of the 20 year average. Thus, catch fractions for case 5 has been estimated from the maximum total catch taken from the four generation moving averages (Frohne 1983).

Appendix C

Estimated Present and Future Design Capacities for Salmon and Trout Hatcheries

A note on using Appendix #C: The tables shown here summarize estimated annual production capacities for salmon and trout by hatchery for each species. The capacities reflect what the hatchery is capable of producing for an interval in the life of the hatchery. Broodstock buildup (internally calculated in the program) may produce estimates of actual fish on hand which are +slightly less than the physical capacity. Capacities for each hatchery for this production case are listed by hatchery species (or stock) and by year intervals. Each section corresponds to a different commercial fish management area. More than one salmon species and hatchery may occur on a given page.

1984 DESIGN CAPACITIES
(in millions)

ALASKA PENINSULA

Hatchery: Russell Creek
Species: Chum

Capacity from 1984 to 1985:

Green egg	12.510
Eyed egg	11.260
Emergent fry	10.700
Fed fry	10.200
Fingerling	9.700
Smolt	NA

Capacity from 1986 to 2003:

Green egg	40.000
Eyed egg	36.000
Emergent fry	34.200
Fed fry	32.490
Fingerling	30.866
Smolt	NA

1984 DESIGN CAPACITIES
(in millions)

COOK INLET

Hatchery: Eklutna
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.100
Eyed egg	0.090
Emergent fry	0.086
Fed fry	0.081
Fingerling	0.077
Smolt	0.062

Species: Chum
Capacity from 1984 to 2003:

Green egg	20.000
Eyed egg	18.000
Emergent fry	17.100
Fed fry	16.200
Fingerling	15.400
Smolt	NA

Species: Coho and (R)
Capacity from 1984 to 2003:

Green egg	0.300
Eyed egg	0.270
Emergent fry	0.257
Fed fry	0.244
Fingerling	0.231
Smolt	0.185

Species: Pink
Capacity from 1984 to 1985:

Green egg	5.000
Eyed egg	4.500
Emergent fry	4.300
Fed fry	4.100
Fingerling	3.900
Smolt	NA

Species: Pink
Capacity from 1988 to 1989:

Green egg	7.000
Eyed egg	6.300
Emergent fry	5.990
Fed fry	5.690
Fingerling	5.400
Smolt	NA

- continued -

COOK INLET (continued)

Hatchery: Fort Richardson
Species: Chinook

Capacity from 1984 to 1986:		Capacity from 1987 to 2003:	
Green egg	1.380	Green egg	1.610
Eyed egg	1.240	Eyed egg	1.450
Emergent fry	0.886	Emergent fry	1.380
Fed fry	0.842	Fed fry	1.300
Fingerling	0.800	Fingerling	1.250
Smolt	0.640	Smolt	1.000

Species: Coho

Capacity from 1984 to 1985:		Capacity from 1986 to 2003:	
Green egg	1.290	Green egg	3.240
Eyed egg	1.160	Eyed egg	2.916
Emergent fry	1.100	Emergent fry	2.770
Fed fry	1.050	Fed fry	2.632
Fingerling	1.000	Fingerling	2.500
Smolt	0.320	Smolt	2.000

Species: Rainbow

Capacity from 1984 to 2003:	
Green egg	2.705
Eyed egg	2.164
Emergent fry	1.840
Fed fry	1.655
Fingerling	1.622
Smolt	0.120

Species: Steelhead

Capacity from 1984 to 2003:	
Green egg	0.200
Eyed egg	0.160
Emergent fry	0.136
Fed fry	0.122
Fingerling	0.122
Smolt	0.120

Hatchery: Kasilof
Species: Sockeye

Capacity from 1984 to 2003:	
Green egg	22.570
Eyed egg	20.320
Emergent fry	19.300
Fed fry	3.000
Fingerling	15.500
Smolt	NA

- continued -

COOK INLET (continued)

Hatchery: Trail Lakes
Species: Chinook
Capacity from 1984 to 2003:

Green egg	3.860
Eyed egg	3.470
Emergent fry	3.300
Fed fry	3.200
Fingerling	3.100
Smolt	NA

Species: Coho
Capacity from 1984 to 2003:

Green egg	4.877
Eyed egg	4.389
Emergent fry	4.170
Fed fry	3.961
Fingerling	3.763
Smolt	NA

Species: Coho (LL)
Capacity from 1984 to 2003:

Green egg	1.085
Eyed egg	0.976
Emergent fry	0.927
Fed fry	0.881
Fingerling	0.837
Smolt	NA

Species: Sockeye
Capacity from 1984 to 2003:

Green egg	31.950
Eyed egg	27.160
Emergent fry	25.800
Fed fry	24.300
Fingerling	NA
Smolt	NA

Hatchery: Tutka
Species: Pink
Capacity from 1984 to 2003:

Green egg	29.970
Eyed egg	25.470
Emergent fry	24.200
Fed fry	12.110
Fingerling	10.900
Smolt	NA

- continued -

COOK INLET (continued)

Hatchery: Big Lake
Species: Coho

Capacity from 1984 to 1985:

Green egg	4.000
Eyed egg	3.720
Emergent fry	3.530
Fed fry	3.360
Fingerling	3.190
Smolt	NA

Capacity from 1986 to 2003:

Green egg	10.000
Eyed egg	9.300
Emergent fry	8.835
Fed fry	8.393
Fingerling	7.974
Smolt	NA

Species: Sockeye

Capacity from 1984 to 1985:

Green egg	15.980
Eyed egg	13.580
Emergent fry	12.900
Fed fry	8.000
Fingerling	NA
Smolt	NA

Capacity from 1986 to 2003:

Green egg	20.000
Eyed egg	14.000
Emergent fry	13.300
Fed fry	12.635
Fingerling	NA
Smolt	NA

Hatchery: Elmendorf
Species: Chinook

Capacity from 1984 to 2003:

Green egg	1.637
Eyed egg	1.473
Emergent fry	1.400
Fed fry	1.330
Fingerling	1.263
Smolt	1.200

Species: Coho (A)

Capacity from 1984 to 2003:

Green egg	1.015
Eyed egg	0.914
Emergent fry	0.868
Fed fry	0.781
Fingerling	0.300
Smolt	0.385

1984 DESIGN CAPACITIES
(in millions)

KODIAK

Hatchery: Frazer Fish Pass
Species: Sockeye
Capacity from 1984 to 2001:

Standard capacities do not apply here since the stock is being rehabilitated with a fishpass. Linear recruitment function used to estimate production and catch.

Hatchery: Karluk
Species: Sockeye
Capacity from 1984 to 2003:

Green egg	25.000
Eyed egg	21.250
Emergent fry	8.500
Fed fry	NA
Fingerling	NA
Smolt	NA

Hatchery: Kitoi
Species: Pink
Capacity from 1984 to 2003:

Green egg	100.000
Eyed egg	90.000
Emergent fry	85.500
Fed fry	12.630
Fingerling	12.000
Smolt	NA

1984 DESIGN CAPACITIES
(in millions)

KOTZEBUE

Hatchery: Sikusuilaq Springs
Species: Chum
Capacity from 1984 to 2003:

Green egg	2.000
Eyed egg	1.800
Emergent fry	1.710
Fed fry	1.624
Fingerling	1.624
Smolt	NA

1984 DESIGN CAPACITIES
(in millions)

PRINCE WILLIAM SOUND

Hatchery: Esther Lake
Species: Chinook
Capacity from 1987 to 2003:

Green egg	0.0500
Eyed egg	0.0475
Emergent fry	0.0451
Fed fry	0.0429
Fingerling	0.0386
Smolt	0.0309

Species: Chinook (LK)
Capacity from 1987 to 2003:

Green egg	0.950
Eyed egg	0.903
Emergent fry	0.857
Fed fry	0.815
Fingerling	NA
Smolt	NA

Species: Chum
Capacity from 1984 to 1985:

Green egg	10.000
Eyed egg	9.000
Emergent fry	8.600
Fed fry	8.500
Fingerling	NA
Smolt	NA

Capacity from 1986 to 2003:

Green egg	111.000
Eyed egg	100.000
Emergent fry	95.000
Fed fry	94.000
Fingerling	NA
Smolt	NA

Species: Coho
Capacity from 1987 to 2003:

Green egg	0.100
Eyed egg	0.095
Emergent fry	0.090
Fed fry	0.086
Fingerling	0.077
Smolt	0.062

Species: Coho (LK)
Capacity from 1986 to 2003:

Green egg	0.917
Eyed egg	0.871
Emergent fry	0.827
Fed fry	0.786
Fingerling	NA
Smolt	NA

- continued -

PRINCE WILLIAM SOUND (continued)

Hatchery: Esther Lake (continued)
Species: Pink

Capacity from 1985 to 1985:

Green egg	36.000
Eyed egg	34.200
Emergent fry	32.500
Fed fry	32.200
Fingerling	NA
Smolt	NA

Capacity from 1986 to 2003:

Green egg	211.000
Eyed egg	200.000
Emergent fry	190.000
Fed Fry	189.000
Fingerling	NA
Smolt	NA

Hatchery: Cannery Creek
Species: Pink

Capacity from 1984 to 2003:

Green egg	50.000
Eyed egg	47.000
Emergent fry	44.650
Fed fry	NA
Fingerling	NA
Smolt	NA

Hatchery: Main Bay
Species: Chum

Capacity from 1984 to 2003:

Green egg	92.980
Eyed egg	83.680
Emergent fry	79.500
Fed fry	26.320
Fingerling	25.000
Smolt	NA

Species: Pink

Capacity from 1984 to 1986:

Green egg	113.800
Eyed egg	102.420
Emergent fry	97.300
Fed fry	NA
Fingerling	NA
Smolt	NA

Capacity from 1987 to 1988:

Green egg	89.400
Eyed egg	80.460
Emergent fry	76.440
Fed fry	NA
Fingerling	NA
Smolt	NA

Capacity from 1989 to 1989:

Green egg	75.440
Eyed egg	67.890
Emergent fry	64.500
Fed fry	NA
Fingerling	NA
Smolt	NA

Species: Pink

Capacity from 1990 to 2003:

Green egg	46.780
Eyed egg	42.110
Emergent fry	40.000
Fed fry	NA
Fingerling	NA
Smolt	NA

- continued -

PRINCE WILLIAM SOUND (continued)

Hatchery: Solomon Gulch
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.050
Eyed egg	0.045
Emergent fry	0.043
Fed fry	0.041
Fingerling	0.039
Smolt	0.031

Species: Chum
Capacity from 1984 to 2003:

Green egg	18.000
Eyed egg	17.100
Emergent fry	16.200
Fed fry	15.400
Fingerling	NA
Smolt	NA

Species: Coho
Capacity from 1984 to 2003:

Green egg	1.000
Eyed egg	0.900
Emergent fry	0.860
Fed fry	0.810
Fingerling	0.770
Smolt	0.730

Species: Pink
Capacity from 1984 to 2003:

Green egg	136.000
Eyed egg	129.200
Emergent fry	122.700
Fed fry	116.600
Fingerling	NA
Smolt	NA

Hatchery: Gulkana
Species: Sockeye
Capacity from 1984 to 2003:

Green egg	30.000
Eyed egg	27.000
Emergent fry	25.110
Fed fry	NA
Fingerling	NA
Smolt	NA

- continued -

PRINCE WILLIAM SOUND (continued)

Hatchery: Perry Island
Species: Chum (a)
Capacity from 1985 to 2003:

Green egg	10.000
Eyed egg	9.000
Emergent fry	8.600
Fed fry	8.100
Fingerling	7.700
Smolt	NA

Species: Pink
Capacity from 1984 to 1984:

Green egg	1.000
Eyed egg	0.900
Emergent fry	0.860
Fed fry	0.810
Fingerling	0.770
Smolt	NA

Capacity from 1985 to 2003:

Green egg	10.000
Eyed egg	9.000
Emergent fry	8.600
Fed fry	0.810
Fingerling	0.770
Smolt	NA

(a) Note hatchery did not operate in 1985.

1984 DESIGN CAPACITIES
(in millions)

SOUTHEAST

Hatchery: Neets Bay
Species: Chinook
Capacity from 1984 to 2003:

Green egg	2.000
Eyed egg	1.800
Emergent fry	1.710
Fed fry	1.625
Fingerling	1.543
Smolt	1.235

Species: Chum (F)

Capacity from 1984 to 1984:		Capacity from 1985 to 1985:		Capacity from 1986 to 1986:	
Green egg	50.000	Green egg	45.000	Green egg	35.000
Eyed egg	46.000	Eyed egg	41.400	Eyed egg	32.200
Emergent fry	44.600	Emergent fry	40.200	Emergent fry	31.200
Fed fry	44.600	Fed fry	40.200	Fed fry	31.200
Fingerling	42.400	Fingerling	38.200	Fingerling	29.700
Smolt	NA	Smolt	NA	Smolt	NA

Species: Chum (F)
Capacity from 1987 to 2003:

Green egg	30.000
Eyed egg	27.600
Emergent fry	26.800
Fed fry	26.800
Fingerling	25.400
Smolt	NA

Species: Chum (S)

Capacity from 1984 to 1984:		Capacity from 1985 to 1985:		Capacity from 1986 to 1986:	
Green egg	10.000	Green egg	15.000	Green egg	25.000
Eyed egg	9.200	Eyed egg	13.800	Eyed egg	23.000
Emergent fry	8.900	Emergent fry	13.400	Emergent fry	22.310
Fed fry	8.900	Fed fry	13.400	Fed fry	22.310
Fingerling	8.500	Fingerling	12.700	Fingerling	21.195
Smolt	NA	Smolt	NA	Smolt	NA

Species: Chum (S)
Capacity from 1987 to 2003:

Green egg	30.000
Eyed egg	27.600
Emergent fry	26.800
Fed fry	26.800
Fingerling	25.400
Smolt	NA

- continued -

SOUTHEAST (continued)

Hatchery: Neets Bay (continued)
Species: Coho
Capacity from 1984 to 2003:

Green egg	5.000
Eyed egg	4.500
Emergent fry	4.300
Fed fry	4.300
Fingerling	3.800
Smolt	NA

Hatchery: Klawock
Species: Chum

Capacity from 1984 to 1984:

Green egg	53.800
Eyed egg	48.420
Emergent fry	46.000
Fed fry	26.320
Fingerling	25.000
Smolt	NA

Capacity from 1985 to 2003:

Green egg	66.500
Eyed egg	59.850
Emergent fry	58.055
Fed fry	26.320
Fingerling	25.000
Smolt	NA

Capacity from 1984 to 1986:

Green egg	14.970
Eyed egg	13.470
Emergent fry	12.800
Fed fry	6.320
Fingerling	6.000
Smolt	NA

Species: Chum
Capacity from 1987 to 2003:

Green egg	29.240
Eyed egg	26.320
Emergent fry	25.000
Fed fry	13.330
Fingerling	12.000
Smolt	NA

Species: Coho
Capacity from 1984 to 2003:

Green egg	1.510
Eyed egg	1.470
Emergent fry	1.372
Fed fry	1.234
Fingerling	1.111
Smolt	1.000

Species: Steelhead
Capacity from 1984 to 2003:

Green egg	0.030
Eyed egg	0.020
Emergent fry	0.020
Fed fry	0.020
Fingerling	0.020
Smolt	0.014

- continued -

SOUTHEAST (continued)

Hatchery: Whitman Lake
Species: Chinook (R)
Capacity from 1984 to 2003:

Green egg	0.400
Eyed egg	0.360
Emergent fry	0.350
Fed fry	0.350
Fingerling	0.350
Smolt	0.310

Species: Chum (S)
Capacity from 1984 to 1984:

Green egg	10.000
Eyed egg	9.400
Emergent fry	9.100
Fed fry	9.100
Fingerling	8.800
Smolt	NA

Species: Coho
Capacity from 1984 to 2003:

Green egg	1.000
Eyed egg	0.920
Emergent fry	0.892
Fed fry	0.892
Fingerling	0.892
Smolt	0.803

Species: Coho (R)
Capacity from 1985 to 1988:

Green egg	0.100
Eyed egg	0.092
Emergent fry	0.087
Fed fry	0.087
Fingerling	0.087
Smolt	0.079

Capacity from 1989 to 2003:

Green egg	4.000
Eyed egg	3.700
Emergent fry	3.600
Fed fry	3.600
Fingerling	3.600
Smolt	3.200

Species: Sockeye
Capacity from 1984 to 1987:

Green egg	0.504
Eyed egg	0.504
Emergent fry	0.504
Fed fry	0.504
Fingerling	0.504
Smolt	0.350

Capacity from 1988 to 2003:

Green egg	2.500
Eyed egg	1.750
Emergent fry	1.663
Fed fry	1.579
Fingerling	1.500
Smolt	1.200

- continued -

1984 DESIGN CAPACITIES
(in millions)

SOUTHEAST (continued)

Hatchery: Beaver Falls
Species: Sockeye
Capacity from 1984 to 2003:

Green egg	3.000
Eyed egg	2.100
Emergent fry	1.995
Fed fry	1.895
Fingerling	NA
Smolt	NA

Hatchery: Crystal Lake
Species: Chinook
Capacity from 1984 to 1984:

Green egg	2.630
Eyed egg	2.020
Emergent fry	1.698
Fed fry	1.528
Fingerling	1.222
Smolt	0.900

Capacity from 1985 to 2003:

Green egg	4.206
Eyed egg	3.575
Emergent fry	3.003
Fed fry	2.703
Fingerling	2.162
Smolt	1.600

Species: Chum
Capacity from 1984 to 2003:

Green egg	0.320
Eyed egg	0.280
Emergent fry	0.275
Fed fry	0.250
Fingerling	NA
Smolt	NA

Species: Coho
Capacity from 1984 to 2003:

Green egg	1.500
Eyed egg	1.420
Emergent fry	1.410
Fed fry	0.131
Fingerling	0.130
Smolt	0.130

Species: Steelhead
Capacity from 1984 to 2003:

Green egg	0.120
Eyed egg	0.060
Emergent fry	0.062
Fed fry	0.050
Fingerling	0.050
Smolt	0.036

- continued -

SOUTHEAST (continued)

Hatchery: Deer Mountain
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.975
Eyed egg	0.828
Emergent fry	0.762
Fed fry	0.686
Fingerling	0.617
Smolt	0.500

Hatchery: Sheldon Jackson
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.050
Eyed egg	0.045
Emergent fry	0.043
Fed fry	0.041
Fingerling	0.039
Smolt	0.031

Species: Chum
Capacity from 1984 to 2003:

Green egg	3.000
Eyed egg	2.700
Emergent fry	2.600
Fed fry	2.400
Fingerling	NA
Smolt	NA

Species: Coho
Capacity from 1984 to 1986:

Green egg	0.060
Eyed egg	0.054
Emergent fry	0.051
Fed fry	0.049
Fingerling	0.046
Smolt	0.037

Capacity from 1987 to 2003:

Green egg	0.200
Eyed egg	0.180
Emergent fry	0.170
Fed fry	0.160
Fingerling	0.150
Smolt	0.120

Species: Pink
Capacity from 1984 to 2003:

Green egg	12.000
Eyed egg	11.400
Emergent fry	10.900
Fed fry	NA
Fingerling	NA
Smolt	NA

- continued -

SOUTHEAST (continued)

Hatchery: Burnett Inlet
Species: Chum
Capacity from 1984 to 2003:

Green egg	5.000
Eyed egg	4.500
Emergent fry	4.400
Fed fry	4.400
Fingerling	4.300
Smolt	NA

Species: Coho

Capacity from 1984 to 1987:		Capacity from 1988 to 2003:	
Green egg	0.050	Green egg	0.100
Eyed egg	0.045	Eyed egg	0.090
Emergent fry	0.044	Emergent fry	0.086
Fed fry	0.044	Fed fry	0.081
Fingerling	0.043	Fingerling	0.077
Smolt	0.035	Smolt	0.062

Species: Pink
Capacity from 1984 to 2003:

Green egg	10.000
Eyed egg	9.000
Emergent fry	8.800
Fed fry	8.700
Fingerling	8.600
Smolt	NA

Hatchery: Burro Creek Farms
Species: Chum

Capacity from 1984 to 1985:		Capacity from 1986 to 2003:	
Green egg	1.000	Green egg	8.000
Eyed egg	0.900	Eyed egg	7.200
Emergent fry	0.890	Emergent fry	7.100
Fed fry	0.880	Fed fry	7.100
Fingerling	0.860	Fingerling	6.900
Smolt	NA	Smolt	NA

Species: Pink

Capacity from 1984 to 1986:		Capacity from 1987 to 1988:		Capacity from 1989 to 1989:	
Green egg	113.800	Green egg	89.400	Green egg	75.440
Eyed egg	102.420	Eyed egg	80.460	Eyed egg	67.890
Emergent fry	97.300	Emergent fry	76.440	Emergent fry	64.500
Fed fry	NA	Fed fry	NA	Fed fry	NA
Fingerling	NA	Fingerling	NA	Fingerling	NA
Smolt	NA	Smolt	NA	Smolt	NA

- continued -

SOUTHEAST (continued)

Hatchery: Gunnuk Creek
Species: Chum

Capacity from 1984 to 1984:

Green egg	2.000
Eyed egg	1.800
Emergent fry	1.710
Fed fry	1.625
Fingerling	NA
Smolt	NA

Capacity from 1985 to 2003:

Green egg	5.000
Eyed egg	4.500
Emergent fry	4.275
Fed fry	4.061
Fingerling	NA
Smolt	NA

Species: Pink
Capacity from 1984 to 2003:

Green egg	1.000
Eyed egg	0.900
Emergent fry	0.855
Fed fry	0.812
Fingerling	NA
Smolt	NA

Hatchery: Hidden Falls
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.405
Eyed egg	0.364
Emergent fry	0.346
Fed fry	0.329
Fingerling	0.313
Smolt	0.250

Hatchery: Kowee Creek
Species: Chum
Capacity from 1984 to 2003:

Green egg	1.500
Eyed egg	1.430
Emergent fry	1.410
Fed fry	1.380
Fingerling	NA
Smolt	NA

Species: Pink
Capacity from 1984 to 2003:

Green egg	8.500
Eyed egg	7.900
Emergent fry	7.800
Fed fry	7.400
Fingerling	NA
Smolt	NA

- continued -

SOUTHEAST (continued)

Hatchery: Medvejie Creek
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.100
Eyed egg	0.090
Emergent fry	0.089
Fed fry	0.088
Fingerling	0.087
Smolt	0.087

Species: Chum
Capacity from 1984 to 1984:

Green egg	6.000
Eyed egg	5.600
Emergent fry	5.500
Fed fry	5.400
Fingerling	NA
Smolt	NA

Capacity from 1985 to 2003:

Green egg	24.000
Eyed egg	22.200
Emergent fry	22.000
Fed fry	21.800
Fingerling	NA
Smolt	NA

Species: Coho
Capacity from 1984 to 2003:

Green egg	1.600
Eyed egg	1.440
Emergent fry	1.368
Fed fry	1.300
Fingerling	1.235
Smolt	NA

Hatchery: Port San Juan
Species: Chum
Capacity from 1984 to 2003:

Green egg	11.100
Eyed egg	10.000
Emergent fry	9.500
Fed fry	9.400
Fingerling	NA
Smolt	NA

Species: Pink
Capacity from 1984 to 2003:

Green egg	114.000
Eyed egg	108.300
Emergent fry	102.900
Fed fry	101.900
Fingerling	NA
Smolt	NA

- continued -

SOUTHEAST (continued)

Hatchery: Port Armstrong
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.050
Eyed egg	0.045
Emergent fry	0.043
Fed fry	0.041
Fingerling	0.039
Smolt	0.031

Species: Chum

Capacity from 1984 to 1989:

Green egg	4.000
Eyed egg	3.600
Emergent fry	3.400
Fed fry	3.200
Fingerling	3.100
Smolt	NA

Capacity from 1990 to 2003:

Green egg	16.000
Eyed egg	14.400
Emergent fry	13.680
Fed fry	12.996
Fingerling	12.346
Smolt	NA

Species: Pink

Capacity from 1984 to 1989:

Green egg	12.000
Eyed egg	10.800
Emergent fry	10.300
Fed fry	9.700
Fingerling	NA
Smolt	NA

Capacity from 1990 to 2003:

Green egg	0.0
Eyed egg	NA
Emergent fry	NA
Fed fry	NA
Fingerling	NA
Smolt	NA

Hatchery: Sandy Bay
Species: Chum

Capacity from 1984 to 1986:

Green egg	3.200
Eyed egg	2.900
Emergent fry	2.700
Fed fry	2.600
Fingerling	2.500
Smolt	NA

Capacity from 1987 to 1989:

Green egg	12.000
Eyed egg	10.800
Emergent fry	10.300
Fed fry	2.632
Fingerling	2.500
Smolt	NA

Capacity from 1990 to 2003:

Green egg	25.600
Eyed egg	23.000
Emergent fry	21.900
Fed fry	2.632
Fingerling	2.500
Smolt	NA

Capacity from 1984 to 1984:

Green egg	16.500
Eyed egg	14.600
Emergent fry	14.100
Fed fry	NA
Fingerling	NA
Smolt	NA

Capacity from 1985 to 1986:

Green egg	33.600
Eyed egg	30.200
Emergent fry	28.700
Fed fry	NA
Fingerling	NA
Smolt	NA

Capacity from 1987 to 1987:

Green egg	26.400
Eyed egg	23.800
Emergent fry	22.600
Fed fry	NA
Fingerling	NA
Smolt	NA

- continued -

1984 DESIGN CAPACITIES
(in millions)

SOUTHEAST (continued)

Hatchery: Sheep Creek
Species: Chum
Capacity from 1984 to 2003:

Green egg	3.000
Eyed egg	2.900
Emergent fry	2.800
Fed fry	2.800
Fingerling	NA
Smolt	NA

Species: Pink
Capacity from 1984 to 2003:

Green egg	34.500
Eyed egg	32.800
Emergent fry	32.500
Fed fry	31.800
Fingerling	NA
Smolt	NA

Hatchery: Snettisham
Species: Chinook

Capacity from 1984 to 1986:		Capacity from 1987 to 2003:	
Green egg	2.188	Green egg	4.000
Eyed egg	1.969	Eyed egg	3.600
Emergent fry	1.871	Emergent fry	3.420
Fed fry	1.684	Fed fry	3.249
Fingerling	1.600	Fingerling	3.086
Smolt	1.200	Smolt	2.469

Species: Chum

Capacity from 1984 to 1986:		Capacity from 1987 to 2003:	
Green egg	14.000	Green egg	71.000
Eyed egg	12.600	Eyed egg	63.900
Emergent fry	11.340	Emergent fry	57.510
Fed fry	10.773	Fed fry	54.630
Fingerling	10.234	Fingerling	51.900
Smolt	NA	Smolt	NA

Species: Coho

Capacity from 1984 to 1986:		Capacity from 1987 to 2003:	
Green egg	1.486	Green egg	1.542
Eyed egg	1.367	Eyed egg	1.418
Emergent fry	1.340	Emergent fry	1.390
Fed fry	1.207	Fed fry	1.250
Fingerling	0.375	Fingerling	1.125
Smolt	0.300	Smolt	0.900

1984 DESIGN CAPACITIES
(in millions)

YUKON

Hatchery: Clear
Species: Chinook
Capacity from 1984 to 2003:

Green egg	0.220
Eyed egg	0.200
Emergent fry	0.188
Fed fry	0.178
Fingerling	0.170
Smolt	NA

Species: Chum
Capacity from 1984 to 2003:

Green egg	0.520
Eyed egg	0.470
Emergent fry	0.445
Fed fry	0.422
Fingerling	0.401
Smolt	NA

Hatchery: Clear
Species: Rainbow
Capacity from 1984 to 2003:

Green egg	1.667
Eyed egg	1.334
Emergent fry	1.134
Fed fry	1.020
Fingerling	1.000
Smolt	NA

Appendix D

Assumptions for Survival of Enhancement-Produced Fish in the Hatchery and in the Natural Environment

A note on Appendix D: Survival assumptions for each species by hatchery, lifestage, and management area are included in this section. Survival assumptions reflect an estimate of the most likely long-term survivals for each species of stock of fish at a given facility. Predictions have been based on a synthesis of past survival data and/or performance of an identical species in a similar program or location. The predicted survival rates also reflect any uncertainties associated with the hatchery that might affect average survivals over time. A key explaining the terms used in the table follows:

HATCHERY SURVIVALS FROM PREVIOUS LIFE STAGE

Abbreviated terms used in Appendix D.	Meaning of abbreviated terms
EY	Hatchery survival fr. green egg to eyed egg
EM	Hatchery survival fr. eyed egg to emerg. fry
FD	Hatchery survival fr. emerg. fry to fingerling
SM	Hatchery survival fr. fingerling to smolt

MARINE SURVIVALS TO ADULT FROM:

Abbreviated terms used in Appendix D.	Meaning of abbreviated terms
EM	Marine survival fr. emergent fry to adult
FD	Marine survival fr. fed fry to adult
FG	Marine survival fr. fingerling to adult
SM	Marine survival fr. smolt to adult

ABBREVIATED TERMS FOR SPECIES

Abbreviated terms used in Appendix D.	Meaning of abbreviated terms
R	Rehabilitation project
LL	Landlocked lake fish plant
LK	Lake plant
SUB	Fish planted at a sub catchable size
CAT	Fish planted at a catchable size

MANAGEMENT AREA: Alaska Peninsula

Hatchery	Species	Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
		EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Russell Cr	Chum	90	95	95	95				2.0	

MANAGEMENT AREA: Cook Inlet

Hatchery	Species	Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
		EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Big Lake	Coho	93	95	95	95				1.0	
Big Lake	Coho (R)									
Big Lake	Sockeye	70	95	95				1.6		
Big Lake	Sockeye (R)									
Eklutna	Chinook	90	95	95	95	80				2.0
Eklutna	Chum	90	95	95	95				2.0	
Eklutna	Coho	90	95	95	95	80				5.0
Eklutna	Coho (R)	90	95	95	95	80				5.0
Eklutna	Pink	90	95	95	95				2.0	
Elmendorf	Chinook	90	95	95	95	95				2.0
Elmendorf	Coho	90	95	90	100	80		0.5	1.0	5.0
Elmendorf	Rainbow	90	98	85	60 SUB	98 CAT		37.5 SUB		75.0 CAT
Ft Richardson	Chinook	90	95	95	95	80				2.0
Ft Richardson	Coho	90	95	95	95	80			1.0	5.0
Ft Richardson	Rainbow	80	85	90	98 SUB	98 CAT		37.5		75.0
Ft Richardson	Steelhead	80	85	90	98	98				1.5
Kasilof	Sockeye	90	95	95	95				12.5	1.0
Trail Lakes	Chinook	90	95	95	95					0.6
Trail Lakes	Coho	90	95	95	95					1.0
Trail Lakes	Coho (LL)	90	95	95	95					50.0
Trail Lakes	Sockeye	70	95	95					1.0	
Tutka	Pink	85	95	100	90			3.0		6.0

MANAGEMENT AREA: Kodiak

		Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
Hatchery	Species	EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Karluk	Sockeye	85	40				1.0			
Karluk	Sockeye (R)									
Kitoi	Pink	90	95	95	95		1.7		3.2	

MANAGEMENT AREA: Kotzebue

		Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
Hatchery	Species	EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Sikusuilaq	Chum	90	95	95				1.0		

MANAGEMENT AREA: Prince William Sound

Hatchery	Species	Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
		EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Cannery Cr	Pink	94	95				3.0			
Esther Lake	Chinook	90	95	95	90	80				3.0
Esther Lake	Chinook (LK)	90	95	95				1.0		
Esther Lake	Chum	90	95	95				1.5		
Esther Lake	Coho (LK)	90	95	95				1.0		
Esther Lake	Coho	90	95	95	90	80				5.0
Esther Lake	Pink	95	95	99				3.5		
Gulkana	Sockeye	90	93				1.0			
Main Bay	Chum	90	95	95	95		0.7	1.5	2.0	
Main Bay	Pink	90	95	95	95		3.0	3.5	5.0	
Perry Island	Chum	90	95	95	95				2.0	
Perry Island	Pink	90	95	95	95				3.0	
Port San Juan	Chum	90	95	99				1.5		
Port San Juan	Pink	95	95	99				3.5		
Solomon Gulch	Chinook	90	95	95	95	80				2.0
Solomon Gulch	Chum	95	95	95				1.5		
Solomon Gulch	Coho	90	95	95	95	80				5.0
Solomon Gulch	Pink	90	95	95				3.5		

MANAGEMENT AREA: Southeast

Hatchery	Species	Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
		EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Beaver Falls	Sockeye	70	95	95				1.0		
Burnett Inlet	Chum	90	95	95	95				2.0	
Burnett Inlet	Coho	90	95	95	95	80				5.0
Burnett Inlet	Pink	90	95	95	95				2.0	
Burro Creek	Chum	90	95	95	95				2.0	
Burro Creek	Pink	90	95	95				1.0		
Crystal Lake	Chinook	85	84	90	80	74				3.0
Crystal Lake	Chum	88	98	80				1.0		
Crystal Lake	Coho	90	93	98	98	96	0.7	1.0		5.0
Crystal Lake	Steelhead	53	85	85	85	80				3.0
Deer Mountain	Chinook	85	92	90	90	81				3.0
Gunnuk Creek	Chum	90	95	95				1.0		
Gunnuk Creek	Pink	90	95	95				1.0		
Hidden Falls	Chinook	90	95	95	95	80				3.0
Hidden Falls	Chum	93	97	98	98		0.7		3.0	
Klawock	Chum	90	95	95	95		0.7		2.0	
Klawock	Coho	87	95	95	95	90				5.0
Klawock	Steelhead	78	94	95	95	80		1.0		3.0
Kowee Creek	Chum	95	99	98				1.0		
Kowee Creek	Pink	93	99	95				2.0		
Medvejie Cr	Chinook	90	95	95	95	80				3.0
Medvejie Cr	Chum	92.5	95	95				1.0		
Medvejie Cr	Coho	90	95	95	95				2.5	

MANAGEMENT AREA: Southeast (continued)

Hatchery	Species	Hatchery survivals from previous life stages (%) EY%	EM%	FD%	FG%	SM%	Marine survivals from previous life stages to adult (%) EM%	FD%	FG%	SM%
Meyers Chuck	Coho	90	95	95	95	80				5.0
Meyers Chuck	Pink	90	95	95				1.0		
Neets Bay	Chinook	90	95	95	95	80				3.0
Neets Bay	Chum (F)	92	97	100	95				3.0	
Neets Bay	Chum (S)	92	97	100	95				2.0	
Neets Bay	Coho	90	95	100	100	88				10.5
Port Armstrong	Chinook	90	95	95	95	80				3.0
Port Armstrong	Chum	90	95	95	95				2.0	
Port Armstrong	Pink	90	95	95				1.0		
Sandy Bay	Chum	90	95	95	95		0.7	1.0	2.0	
Sandy Bay	Pink	90	95				0.7			
Sheep Creek	Chum	95	99	98				1.0		
Sheep Creek	Pink	95	99	98				2.0		
Sheldon Jackson	Chinook	90	95	95	95	80				3.0
Sheldon Jackson	Chum	90	95	95				1.0		
Sheldon Jackson	Coho	90	95	95	95	80				3.0
Sheldon Jackson	Pink	95	96				2.1			
Snettisham	Chinook	90	95	90	95	75				3.0
Snettisham	Chum	90	95	95	95				2.0	

MANAGEMENT AREA: Southeast (continued)

Hatchery	Species	Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
		EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Snettisham	Coho	92	98	90	90	80		1.0		5.0
Whitman Lake	Chinook	90	97	100	100	90				3.0
Whitman Lake	Chum (S)	94	97	100	97				3.0	
Whitman Lake	Coho	92	97	100	100	90				6.0
Whitman Lake	Coho	92	97	100	100	90				5.0
Whitman Lake	Sockeye	70	95	95	95	80				10.0

MANAGEMENT AREA: Yukon

Hatchery	Species	Hatchery survivals from previous life stages (%)					Marine survivals from previous life stages to adult (%)			
		EY%	EM%	FD%	FG%	SM%	EM%	FD%	FG%	SM%
Clear	Chinook	90	95	95	95				0.6	
Clear	Chum	90	95	95	95				2.0	
Clear	Rainbow	80	85	90	98				37.5	

Appendix E

Assumptions for Capital and Operating Costs of Public and Private Nonprofit Salmon and Trout Hatcheries Over Twenty-Year Life of Economic Analysis

Note on Appendix E: The annual operating and capital costs of hatcheries are projected in the following tables. A Key for column headings follows:

Hatchery	Name of hatchery
Date fr: to:	Beginning to end year of cost forecast
Base operating dollars	Base operating cost per year
Base capital dollars	Base capital cost per year
Administrative dollars	Govt. administrative cost per year
Evaluation dollars	Biological evaluation costs per year
Total dollars	Sum of all above costs per year

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Alaska Peninsula

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Russell Creek	1984 1984	142.0		21.3	21.3	184.6
	1985 1986	427.4		64.1	64.1	555.6
	1987 2003	600.0		90.0	90.0	780.0

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Cook Inlet

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Big Lake	1984 1984	298.9		44.8	44.8	388.0
	1985 1985	324.7		48.7	48.7	422.1
	1986 2003	407.2		61.0	61.0	529.4
Elmendorf	1984 1984	481.8		72.3	72.3	626.3
	1985 1985	475.5		71.3	71.3	618.2
	1986 2003	475.5		71.3	71.3	618.2
Ft Rich	1984 1984	616.0		92.4	92.4	800.8
	1985 1985	664.6		99.7	99.7	864.0
	1986 2003	825.9		124.0	124.0	1073.7
Kasilof	1984 1984	480.0		72.0	72.0	624.0
	1985 2003	591.3		88.7	88.7	768.7
Trail Lakes	1984 1984	381.7		57.3	57.3	496.2
	1985 1989	385.0		57.8	57.8	500.5
	1990 2003	900.0		135.0	135.0	1170.0

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Cook Inlet

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis- trative dollars	Evalua- tion dollars	Total dollars
Tutka	1984 1984	369.8		55.5	55.5	480.7
	1985 2003	420.9		63.1	63.1	547.2

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Kodiak

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Frazer Fish Pass	1984 2003	30.0		4.5	4.5	34.5
Karluk	1984 1984	192.9		28.9	28.9	250.8
	1985 2003	247.9		37.2	37.2	322.3
Kitoi Bay	1984 1984	391.7		58.8	58.8	509.2
	1985 2003	432.8		64.9	64.9	562.6

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Kotzebue

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Administrative dollars	Evaluation dollars	Total dollars
Sikusuilaq Springs	1984 1984	277.9		41.7	41.7	361.3
	1985 2003	342.3		51.4	51.4	445.0

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Prince William Sound

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Cannery Cr	1984 1984	380.2		57.0	57.0	494.3
	1985 1985	441.5		66.2	66.2	574.0
	1986 2003	478.4		71.8	71.8	621.9
Gulkana	1984 1984	127.7		19.2	19.2	166.0
	1985 1985	287.8		43.2	43.2	374.1
	1986 2003	400.0		60.0	60.0	520.0
Main Bay	1984 1984	384.2		57.6	57.6	499.5
	1985 1985	406.7		61.0	61.0	528.7
	1986 2003	572.0		85.8	85.8	743.6

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Southeast

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Beaver Falls	1984 1986	184.8		27.7	27.7	240.2
	1987 2003	254.8		38.2	38.2	331.2
	1987 2003	600.0		90.0	90.0	780.0
Crystal Lake	1984 1984	490.5		73.6	73.6	637.7
	1985 1985	500.4		75.0	75.0	650.5
	1986 2003	575.4		86.3	86.3	748.0
Deer Mountain	1984 1984	175.9		26.4	26.4	228.7
	1985 1985	190.3		28.6	28.6	247.4
	1986 2003	249.0		37.4	37.4	323.7
Hidden Falls	1984 1984	488.8		73.3	73.3	635.4
	1985 1985	549.0		82.4	82.4	713.7
	1986 2003	599.0		89.9	89.9	778.7
Klawock	1984 1984	429.0		64.4	64.4	557.7
	1985 2003	451.0		67.7	67.7	586.3

- continued -

Management area: Southeast (continued)

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Snettisham	1984 1985	458.3[a]		68.8[a]	68.8[a]	595.8
	1986 2003	634.5		95.2	95.2	824.9

a/ Rounding errors (total dollars correct).

1984 ADF&G ANNUAL HATCHERY COSTS
(dollars in thousands)

Management area: Yukon

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Administrative dollars	Evaluation dollars	Total dollars
Clear	1984 1984	314.9[a]		47.2[a]	47.2[a]	409.4
	1985 1985	334.9[a]		50.2[a]	50.2[a]	435.4
	1986 2003	400.0		60.0	60.0	520.0

a/ Rounding errors (total dollars correct).

1984 PNP HATCHERY COSTS
(dollars in thousands)

Management area: Cook Inlet

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis- trative dollars	Evalua- tion dollars	Total dollars
Eklutna	1984 1984	183.0		NA	NA	183.0
	1985 1985	183.0	200.0	NA	NA	383.0
	1986 2003	250.0		NA	NA	250.0

1984 PNP HATCHERY COSTS
(dollars in thousands)

Management area: Prince William Sound

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis-trative dollars	Evalua-tion dollars	Total dollars
Esther Lake	1984 1984	283.4	750.0	NA	NA	783.4
	1985 1985	433.4	8250.0	NA	NA	8683.4
	1986 1986	465.0		NA	NA	465.0
	1987 1988	735.0		NA	NA	735.0
	1989 2003	1050.0		NA	NA	1050.0
Port San Juan	1984 1984	1100.0		NA	NA	1100.0
	1985 1985	610.0	500.0	NA	NA	1110.0
	1986 2003	610.0		NA	NA	610.0
Solomon Gulch	1984 1984	407.0		NA	NA	407.0
	1985 1985	450.0	14.0	NA	NA	464.0
	1986 1987	450.0	50.0	NA	NA	500.0
	1988 2003	525.0		NA	NA	525.0

1984 PNP HATCHERY COSTS
(dollars in thousands)

Management area: Southeast

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Administrative dollars	Evaluation dollars	Total dollars
Burnett Inlet	1984 1984	135.0	965.0[a/]	NA	NA	1100.0
	1985 1985	150.0		NA	NA	150.0
	1986 1987	200.0		NA	NA	200.0
	1988 1988	240.0		NA	NA	240.0
	1989 1989	250.0		NA	NA	250.0
	1990 1992	300.0		NA	NA	300.0
Burnett Inlet (2)	1993 2003	330.0		NA	NA	330.0
Burro Cr Farms	1984 1984	80.0		NA	10.0	90.0
	1985 1985	80.0	40.0	NA	NA	110.0
	1986 1986	100.0	10.0	NA	NA	110.0
	1987 2003	200.0	100.0[a/]	NA	NA	100.0
Gunnuk Cr	1984 1984	120.0		NA	NA	120.0
	1985 2003	150.0		NA	NA	150.0

a/ Sum of Capital, Administrative, and Evaluation costs.

- continued -

Management area: Southeast (continued)

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis- trative dollars	Evalua- tion dollars	Total dollars
Kowee Cr	1984 1984	37.0		NA	NA	37.0
	1985 2003	37.0		NA	NA	37.0
Medvejie Cr	1984 1984	244.0		NA	NA	244.0
	1985 1985	230.0		NA	NA	230.0
	1986 2003	300.0		NA	NA	300.0
Neets Bay	1984 1984	600.0		NA	110.0[a]	710.0
	1985 1985	600.0	400.0	NA	NA	1,000.0
	1986 1986	600.0		NA	NA	600.0
	1987 2003	560.0		NA	NA	560.0
Port Armstrong	1984 1984	200.0		NA	NA	200.0
	1985 1985	200.0		NA	80.0[a]	280.0
	1986 1986	200.0		NA	NA	200.0
	1987 1988	200.0		NA	NA	200.0
	1989 1989	200.0		NA	50.0[a]	250.0
	1990 2003	325.0		NA	NA	325.0

a/ Sum of Administrative and Evaluation costs.

- continued -

Management area: Southeast (continued)

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis- trative dollars	Evalua- tion dollars	Total dollars
Sandy Bay	1984 1984	401.3		NA	NA	401.3
	1985 1985	327.3		NA	NA	327.3
	1986 1986	311.7		NA	NA	311.7
	1987 2003	327.0		NA	NA	327.0
Sheep Cr	1984 1984	198.5	42.0	NA	NA	240.5
	1985 2003	198.5		NA	NA	198.5
Sheldon Jackson	1984 1984	121.0		NA	42.5 a/	206.0
	1985 1985	139.0		NA	39.5 a/	217.5
	1986 1986	148.0		NA	62.5 a/	273.0
	1987 1987	151.0		NA	52.0 a/	203.0
	1988 1988	163.0		NA	232.0 b/	395.0
	1989 1989	167.0		NA	10.0	177.0
Sheldon Jackson 2	1990 1990	169.0		NA	NA	169.0
	1991 2003	170.0		NA	NA	170.0

a/ Estimated sum of Administrative and Evaluation costs.
b/ Estimated sum of Administration, Evaluation and Capital costs.

- continued -

Management area: Southeast (continued)

Hatchery	Date fr: to:	Base operating dollars	Base capital dollars	Adminis- trative dollars	Evalua- tion dollars	Total dollars
Whitman Lake	1984 1984	300.0		NA	NA	300.0
	1985 1985	300.0	220.0	NA	NA	520.0
	1986 1987	396.0		NA	NA	396.0
	1988 1988	540.0	600.0	NA	NA	1,140.0
	1989 2003	540.0		NA	NA	540.0

Appendix F

Brief Documentation and Equations for the Price Forecasting Model

Estimates of future prices have been made using price models based on Muse (1984). As previously alluded to, Muse developed the models specifically to address the price-forecasting needs of the Mini-Cabinet project. The nine final price-forecasting equations that were used in this analysis were developed using linear or semi-log models.

Of particular importance to the benefit-cost study is the behavior of the two functional-model forms. The linear model for all species tends to produce lower price estimates than the semi-log form at high-landings levels. Conversely, the linear model produces higher price estimates at low levels of harvest. For the analysis, both have been used to evaluate enhancement projects. A full accounting of the five original linear models is available in Muse (1984). A brief summary of the models along with some discussion of the limits of econometric price forecasting are covered here for the reader.

In the price models, ex-vessel prices are expressed as simple linear functions of the explanatory variables. Other functional forms could have been used. In order to study the impact of a nonlinear functional form on the results of the benefit-cost analysis, the pink and chum models in Muse have been reestimated substituting the natural logarithm of price for the simple price variable. These so-called "semi-log" models are not as easy to work with as the linear models, and recourse to sophisticated methods for solving systems of nonlinear equations has been necessary.

The explanatory power of the semi-log models appears to be about equal to the linear model. Again, the pink and chum models perform better than the sockeye, coho, and king models. Muse points out, however, that there are some statistical problems in determining how well the semi-log model explains the variability in prices (also created from dealing with systems of nonlinear equations).

While the work of Muse has been judged to be the best available tool for this study, some of the problems with the use of econometric models for forecasting should be identified as follows:

First, the small number of observations, or data points, available and the absence of many relevant data series have imposed severe restrictions on the nature of the models used in the analysis. These restrictions mean that these models can be misspecified and some parameter estimates may be biased.

Second, to use these models to make price estimates, it is necessary to have projections of several important explanatory variables. Obviously, the precision of the variables used affect the precision of the forecast of prices. Some of the critical variables referred to are Alaska salmon landings, US pink salmon landings, prime interest rate, and international exchange rates.

While a lengthy discussion of the difficulties of forecasting catches has already been presented, exchange rates and prime interest rates are also important variables in the discussion. Both the yen and the French franc exchange rate are assumed in future years to be averages of yearly values from the period 1973 to 1983. This interval was chosen since it corresponds roughly to the period following the breakdown of the Bretton Woods fixed-exchange-rate system and the emergence of the flexible exchange-rate system. June pink salmon inventories were predicted, using a model that projected inventories as a function of U.S. pink salmon landings in the previous year and the prime interest rate during the current year. This model may be found in Appendix E. The prime interest rate in the future is projected as a simple average of yearly average rates during the period 1975 to 1984.

Third, the price-forecasting models that have been formulated are believed to reflect important relationships that exist during the period from 1965 to 1984. Should these relationships change in coming years, the relevance of the models will be reduced. For example, the activities of the Alaska Seafood Marketing Institute may produce an outward shift in the consumer demand for salmon products through education and changes in consumer preference. Future changes of this nature could reduce the relevance of salmon models estimated using data from the last two decades.

The final consideration is that if the model were accurately specified, the parameters were estimated without errors, and the relationships reflected in the model continued unchanged through the period of the forecast, any price forecasts made would have associated probability distributions. That is, the forecast provides a "most likely" estimate, but it also has an associated range of possible values. The uncertainty associated with the forecasts of the explanatory variables, such as the ratio of U.S. dollars to Japanese yen, produces the range. Its existence, however, is also a function of econometric models. First, the equations in such a model are each assumed to contain a random-error term. Second, each of the coefficient estimates in the model is assumed to be a random variable with a mean and a variance. It is possible to make forecasts of the dependent variables without reporting the distribution of the estimate. None the less, the distribution exists and the forecast is not a point estimate.

Appendix G

An Approach for Upgraded Bio-Economic Analysis of the Fishery Enhancement Program

Background

The bulk of this report has addressed a specific policy question on the benefits and costs of the enhancement program. Many questions have been left unanswered regarding other economic impacts of the enhancement program that may be of importance to decision makers. While we cannot hope to evolve a fully developed planning or decision-making methodology here, we have included some recommendations on how the enhancement bio-economic analysis could be expanded to treat many critical questions not addressed here. This discussion addresses one approach to the question of how ADF&G could evaluate projects in the future.

Few formal approaches to decision criteria for public fishery investments exist. Furthermore, there has been little documentation of how government should go about implementing fishery-investment criteria.

One notable planning approach has been developed by the Canadian Government, Department of Fisheries and Oceans. This policy-planning framework is currently being formally applied to the Salmonid Enhancement Program (SEP). The authors of this planning process call the methodology a "Multiple Objective Planning Framework" (Anonymous 1977). A thorough discussion of the approach appears in the inhouse document, "The Economic Rationale For Salmonid Enhancement". A brief explanation of the analysis methodology is presented in the following section.

A second but nearly identical approach was developed by Dr. Lee Anderson (1984), 1983 president, economics section, American Fisheries Society. In his summary address at the "1984 Workshop on Salmon and Steelhead Economic Evaluation," Dr. Anderson noted that the optimal approach for a broad bio-economic methodology for government evaluation of salmon and steelhead investment and mitigation strategies would consist of a mix of rigorous economic criteria to deal with *positive analysis* issues and subjective criteria for portions of the analysis. An outline of this approach is also included in the following section. Of key importance is that the two approaches do not attempt to tell decision makers what they should do. They do not provide some simplistic rating system where all variables in the analysis can be focused into one optimal choice. Rather, they provide quantitative information about investments for making informed value judgments and decisions. The painstaking work of making those normative judgments, however, must be made in a climate of increased knowledge.

It is not implied here that state government need only to simplistically adopt one of these frameworks. Clearly, Alaskan salmon-enhancement fishery-policy questions appear to have much in common with others in the Pacific Northwest but probably require a specially tailored evaluation methodology.

Summary of Canadian Multiple Objective Planning Framework

The following narrative is a summarized description of multiple objective planning taken from a Canadian document entitled "The Economic Rationale for Salmonid Enhancement" (Anonymous 1978).

The benefit-cost approach recognizes that society has a multiplicity of goals, some quantifiable in national income terms, others not. In this same context, the benefit-cost analysis of salmonid enhancement proposals also recognizes that fishery-development projects have impacts beyond those measurable in national-income terms. Accordingly, a framework has been developed that attempts to forecast and describe not only the national impacts of salmonid enhancement proposals but also the environmental and distributional impacts.

Specifically, a five-account system has been established to detail the benefits and costs of development based on the criteria in the following identified governmental goal areas:

1. National Income Account
2. Regional Development Account
3. Native People Account
4. Employment Account
5. Resource and Environmental Preservation Account

All benefits and costs measurable in monetary units are measured in the national income account. From the information that appears there, it is possible to establish the net national-income benefits and the benefit-cost ratios for all economic purposes (commercial, recreational, and subsistence fish production) of a proposed development.

The foundation of the national-income account is formal benefit-cost analysis, which focuses on estimating the following information:

A. Benefits

1. The value of commercial fish production, as measured by market prices of fish products.

2. The value of recreational fish production, as measured by the consumer surplus of the sport fishery.

3. The value of subsistence fish production, as measured by the net value of opportunities foregone in the commercial fishery.

B. Costs

1. The costs of commercial fish development and management attributable to enhancement.

2. The costs of capital, materials, and operating costs of fish production facilities.

3. The costs of fish harvesting and processing attributable to enhancement.

4. The costs of land and other natural resources attributable to enhancement.

The regional development account assesses the geographic distribution of income impacts from the project. Of particular importance to that account is the size of the primary fishing-revenue impact, and the probable geographic distribution of that impact, in terms of who will likely catch the enhanced production.

The Native people account measures the economic impacts created by SEP projects on Indian bands. Impacts near the project site, benefits to the Native commercial fleet, increased employment opportunities in the processing sector, and improvement in the food fishery are measured.

The employment account ranks enhancement projects on the basis of primary employment generated and on the probability of recruiting new labor from the ranks of the unemployed.

The resource and environmental preservation account measures the cultural and environmental impacts of an enhancement facility.

With the five-account system, it is possible to account for the real costs of objectives, other than just national-income maximization. The benefits of meeting social objectives that are not measurable in national-income "dollars" and their value are largely a matter of judgments. Within that framework, it becomes possible to integrate the national-income/efficiency aspects of salmonid-enhancement proposals with the broader social and economic potentials of the program. Program choices may be constrained by some minimally required level of net national-income benefits, out of which, for example, it would be possible to recover the government's investment costs. It also allows an optimal balance of social and economic goals to be embodied in a recommended investment plan.

Anderson Decision Analysis Methodology

The following narrative is a summary and list of the "Decision Analysis Methodology" recommended for fishery management, enhancement, and mitigation projects (Anderson 1984).

1. Standard B/C analysis from social-efficiency perspective (components to include in B/C analysis).

    a. Describe policy question - valuation methodology will often change with framing of policy question.

    b. Taxonomy of benefits and costs - formally list what is defined as a benefit and cost.

    c. Methods - input variables, background assumptions for analysis.

    d. Results.

    e. Discussion - describe how results relate to answering policy question; potential biases in analysis; and describe unmeasurable effects.

2. Cost effectiveness: if project is mandated by law, additional cost analysis may be helpful. Standard B/C analysis must always be conducted along with cost effectiveness analysis.

3. Distributional effects: by sector and/or geographically through input-output analysis or econometric model.

4. Other economic impacts: jobs and wages.

5. Cultural or legal implications.

Components of Bio-Economic Decision Criteria for Analysis of State Salmon Enhancement

The decision-making criteria presented here for evaluation of the FRED program draws heavily from the Canadian multiple-objective planning framework and Anderson's decision framework.

This procedure makes it possible for state government to be more aware of the social and economic consequences of salmon fishery enhancement. One of the methods of producing an informed decision-making audience is through a mixture of rigorous evaluation techniques developed and used by economists and fishery-policy analysts. This section not only includes the basic steps for developing decision-making criteria for Alaska but also lists some specific areas that need immediate attention if the steps are to be implemented. Though the focus of decision criteria is for analysis of the enhancement program, many other fisheries issues could be evaluated with such a framework.

Bio-forecasting:

A fundamental part of any economic-evaluation exercise for fishery enhancement must include the quantitative bio-forecasting of the future state of fishery stocks, with and without some proposed action (like an enhancement project). In fact, the very success of any proposed economic-evaluation framework is highly dependent on the precision of project-by-project forecasts of the "net" increase (biological gains and losses over the long term) in the stock of salmon available for harvest from an enhancement project or series of projects. Out of necessity, the forecasting effort would have to deal with a host of biological, fishery, and fish-cultural issues. This evaluation framework must be developed to provide advice and direction to policy makers to ensure that maximal social and economic benefits are derived from extensive application of salmon- and trout-enhancement techniques in Alaska.

A bio-forecasting working group would play a key role in developing forecasts of the changes in salmon stocks from the proposed enhancement efforts. An important function of the upgraded forecasting effort would be to aid in identification and reduction of potential risks and errors that are possible when people attempt to integrate their activities into a complex ecological system. The group would be charged with the following tasks:

1. Develop life-stage survival estimates for enhancement-produced fish, using state-of-the-art fishery forecasting methods. Forecasts must deal with "in hatchery" survivals and natural-environment survivals. They must at least include hatcheries, fish passes, lake fertilization, and stream clearance.

2. Formally incorporate density-dependent aspects of recruitment and expected stock, genetic, or fishery (and management) interactions that may affect the gains and losses in the fishery. This is a critical component in determining the net increase in the statewide harvest from enhancement projects.

3. Provide information of variability, uncertainty, and risk so that formal decision analysis may be incorporated into economic analysis.

4. Develop estimates of other site-specific biological criteria such as age distribution, harvest weight, and fecundity for bio-forecasting.

5. Investigate existing population and management models and recommend least-cost methods for developing theoretical

and applied methods for forecasting models. Also, investigate and make recommendations regarding existing data and systems for gathering data that would be used for improving the precision of bio-forecasts.

Benefit-cost analysis:

As alluded to by the the previous two authors, the benefit-cost analysis is a key step for meaningfully ranking enhancement projects. The components of the B/C analysis must include an estimate of the gross benefits to the commercial fishery and an estimate of the consumer surplus to the sport fishery.

Accounting stance:

The primary emphasis of benefit-cost analysis for fisheries enhancement should be the net benefits to Alaskans, as dealt with in a state-accounting stance. Net benefits to the U.S., however, as covered in a national-accounting stance, should not be ignored. There is a prevailing attitude in the lower 48 that Alaska's economy does not contribute its fair share to the nation as a whole. The net benefits of many fisheries projects, however, may largely be exported. Determining the consumer and producer surplus at the national-income level helps identify our national-income contributions.

Demand Analysis for Commercial Fishery Harvests:

Since Alaska's salmon catch is a large contributor to the world supply of salmon, movements along the demand curve must be considered in the benefit-cost analysis. This makes the use of some form of econometric price-forecasting model necessary. The price-forecasting models used in this analysis should be modified or the data reevaluated so that new models will be applicable to various regions in Alaska. This will allow projects in the state to be evaluated on a case-by-case basis. Further, the validity of these models should be tested by comparing them to other proven econometric models.

Additional demand-modeling work should be conducted at the wholesale level. An effort needs to be made to determine whether the wholesale-price based models will result in better predictions of future prices to commercial fishermen. A further benefit to this type of work may be a better understanding of how the international salmon market works.

Recreational Demand Analysis:

Economists are often asked the question: What is the value of the sport-fishing resource? The question itself is an oversimplification. Angling-resource values are location-dependent, much like property values. They vary greatly from site to site, depending on the fishery's character, the cost or availability of the site to anglers, and the availability of substitute angling of various kinds. A single value provides little help in solving the complex choices managers face. Managers need to know the benefits of specific management options.

Methods are now available for estimating benefits in greater detail. As previously explained, the Sport Fish Division is using some of these methods to evaluate angling-resource values. The results of these studies will answer some but not all of the questions required to rank enhancement projects on a statewide basis. Future work on recreational valuation for enhancement should incorporate willingness-to-pay functions (from ongoing Sport Fish Division work) into benefit-cost models that can be used for comparison of specific projects. Where the developing data base or consumer-surplus functions are not adequate, additional work may be required.

Financing Feasibility Analysis (for PNP hatcheries):

An aggressive salmon-enhancement loan program exists in Alaska for qualifying PNP hatchery operators. A major dimension of the loan process is allocating limited loan funds to applicants with the highest probability of repayment.

While the mechanics of estimating loan repayment are very straightforward, the financing payback of PNP hatcheries is not a very appropriate procedure for benefit-cost analysis. It is usually best to deal with financing payback projections in nominal terms outside of the benefit-cost analysis. The projections, however, may use much of the same information as the benefit-cost analysis. Financing payback equations will not provide decision makers with <u>any</u> useful information on whether Alaskans will be made better or worse off by making a PNP loan. This information can only be determined by a competent benefit-cost analysis or welfare economic analysis. However, financing information is needed and currently used for allocating loan funds. It is quite conceivable that a decision maker faced with two candidate loans having similar efficiency and distributional effects will support the investment with the most feasible loan repayment program. To produce this type of information, it will be necessary to modify or incorporate changes into existing benefit-cost models that will account for cash-flow dynamics of PNP investments and operations.

Distributional Effects:

If a decision maker were only interested in a single objective, namely, the maximization of fishing income, then the economic evaluation would not need to go beyond benefit-cost analysis. Furthermore, most government policy seems to imply a multiplicity of goals. Thus, if the decision maker is also interested in formally dealing with such issues as distributional effects of proposed investments, then it is necessary to expand the scope of the work to impact assessment, which must be dealt with in a modeling framework that is separate from efficiency considerations.

Modeling of distributional effects and secondary impacts of government actions is a specialized area of economics. More than one mathematical approach exists for this type of work. Some of the more familiar frameworks are economic base models, input-output models, and econometric models.

One or more of these types of impact models will be required for the enhancement decision-making criteria. It is apparent that the ADF&G needs to have a flexible regional impact model that can be applied on a project-by-project basis as well as in the state as a whole. The analysis must determine total income and/or employment changes resulting from policy alternatives. It should also provide impact information to address geographical and sector-specific distributional effects and needs to deal with both the commercial fishery and processing sectors as well as the recreational fishery. Since numerous approaches are available for evaluation of distributional effects, it is not appropriate here to discuss the specific questions of how to develop an efficient model(s) for Alaska. Several good candidates for further investigation exist, such as Battelle-Northwest's MASTER econometric model (Scott 1984).

5. Environmental/Cultural/Legal:

As previously alluded to, there are some impacts of fisheries policies and enhancement that can only be partially measured in a formal econometric framework. For example, the religious values associated with the native harvest of salmon are not easily monitized. *Existence* and *option values* of endangered stocks are not easily dealt with in B/C analysis but may be important when endangered stocks are rehabilitated by enhancement. While every effort should be made to include these impacts in the benefit-cost and distributional analysis, it will often be necessary to formally deal with these consequences in an off-to-the-side fashion. This should be accomplished by simply listing the effects (and noting whether they are benefits or costs) that are either not measured or only partially measured in some other part of the analysis.