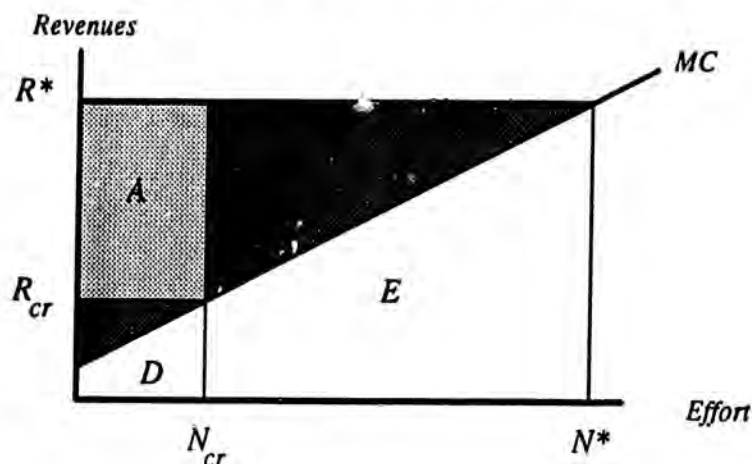


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The concepts can be most readily seen in Figure One. Figure One represents a stylized version of how the total revenues of the fishery are divided up between commercial fishermen and the hatchery operators. On the vertical axis is represented the value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

Figure One: Net benefits calculation



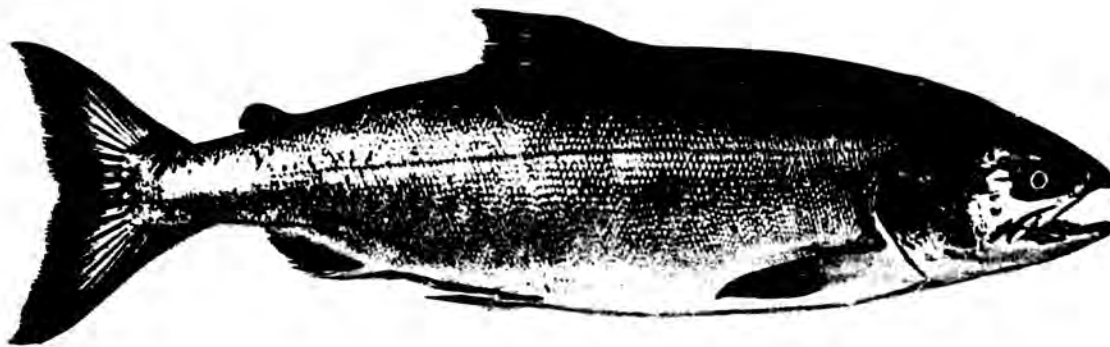
Given that total revenues are such that an individual fisherman may earn revenues of R^* , there will be N^* fishermen who participate in the fishery. Thus, total revenues is the area of the box with height R^* and width N^* , which has value R^*N^* . The total fishing costs associated with earning revenues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

II. RESULTS

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

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

DRAFT CHAPTER IX - ECONOMICS



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

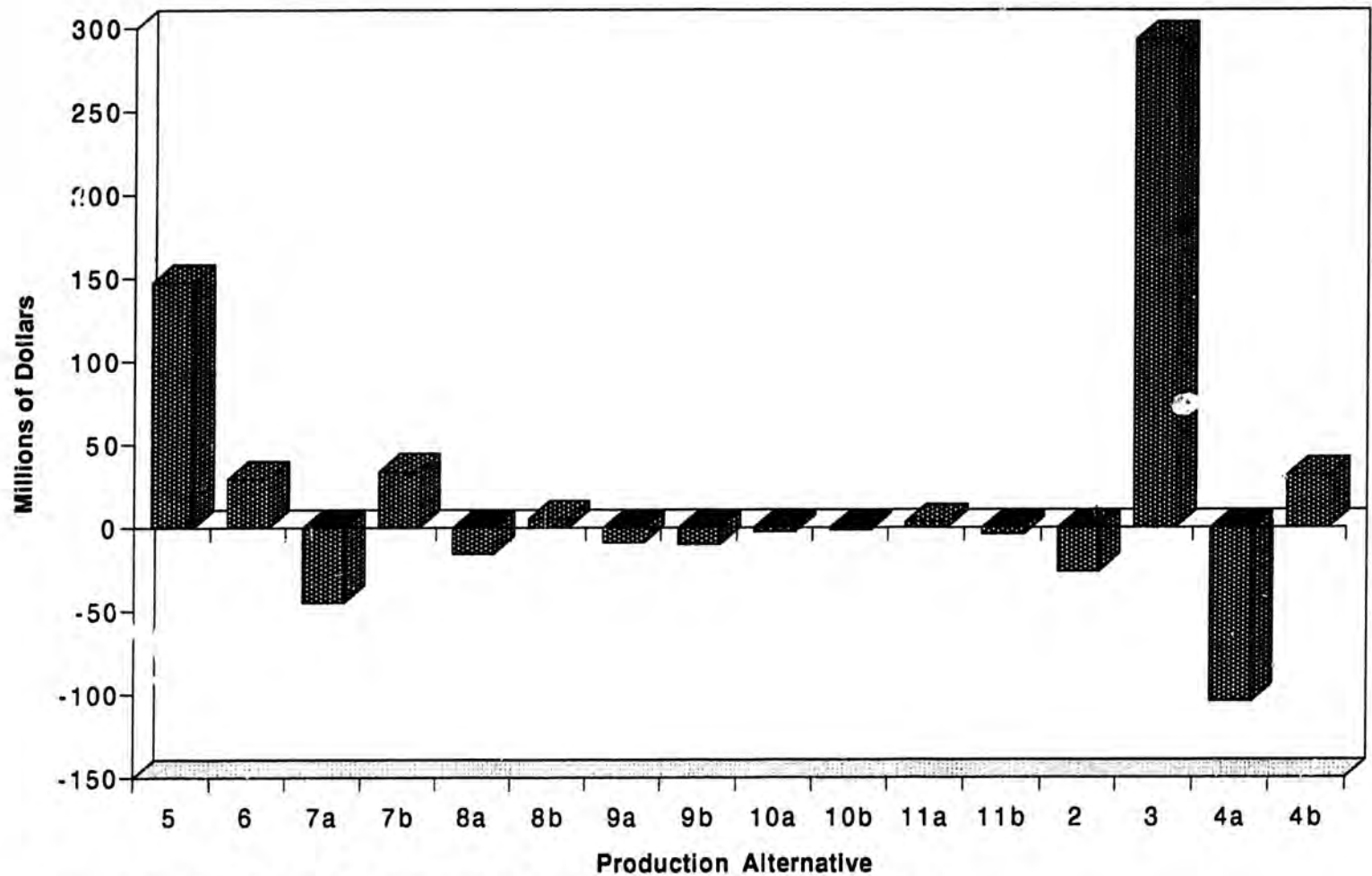
JANUARY 1993

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

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

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

Change in Net Benefits of Production Alternatives for the Salmon Enhancement Program



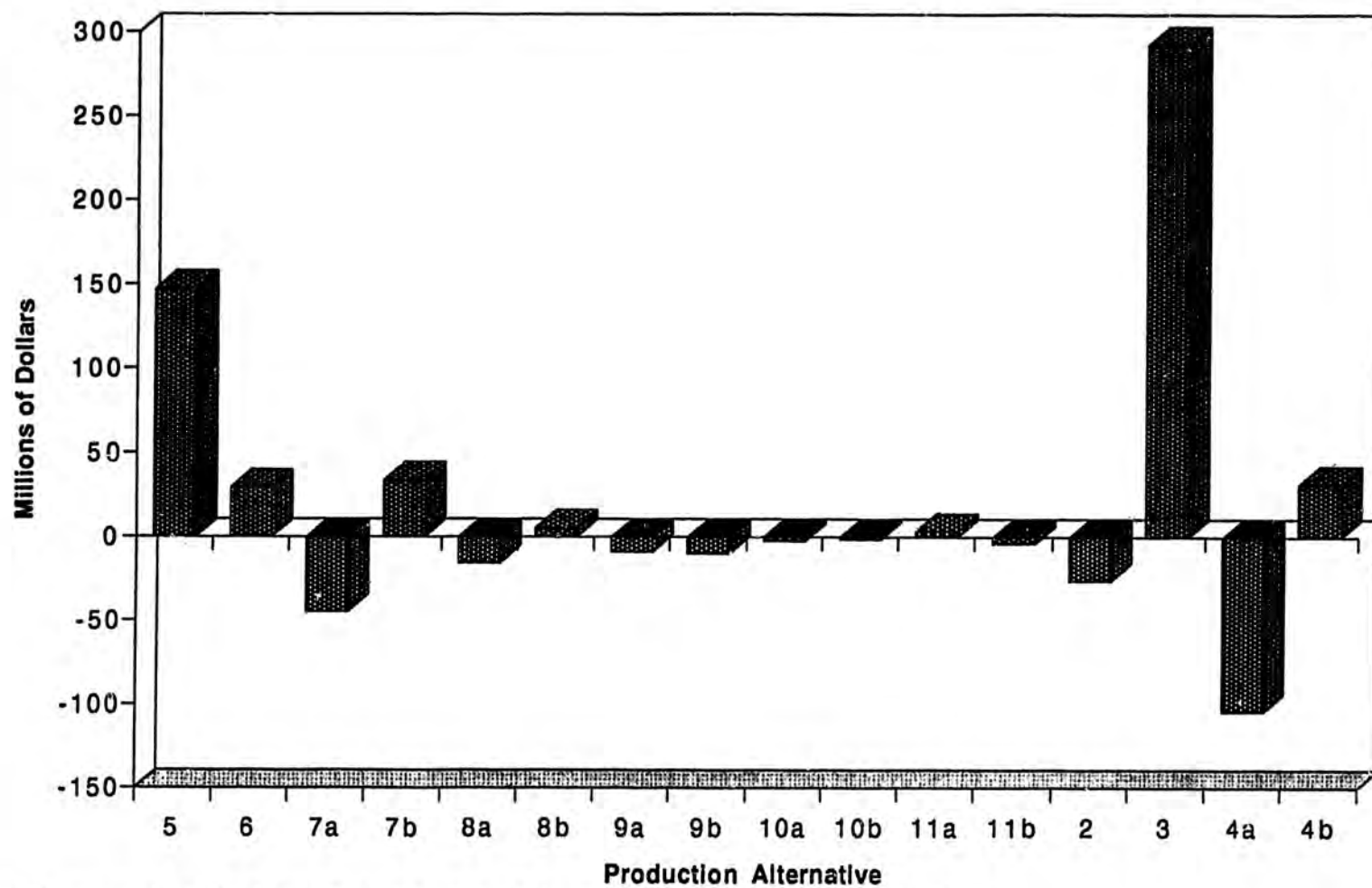
Source: Boyce, et al., 1992, A Benefit-Cost Analysis of the Alaska Salmon Enhancement Program.

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

Policy Alternative	Case #	Western Alaska	Cook Inlet	Kodiak	Prince William S.	Southeast	State Total
Current Production.	1	993.40	276.55	288.69	126.63	737.78	2,423.05
Eliminate Pink Prog.	5	1,016.91	271.01	312.64	95.02	874.81	2,570.39
Eliminate Sockeye Prog.	6	1,036.43	284.07	258.72	119.11	754.07	2,452.41
Increase Pink 15%	7a	990.19	277.31	281.15	116.59	712.88	2,378.12
Decrease Pink 15%	7b	996.61	276.73	293.54	131.11	758.86	2,456.85
Increase Sockeye 15%	8a	987.77	276.36	292.62	126.74	724.09	2,407.57
Decrease Sockeye 15%	8b	999.17	277.54	284.79	123.65	740.23	2,428.38
Increase Chum 15%	9a	992.53	276.15	286.22	123.13	736.14	2,414.18
Decrease Chum 15%	9b	994.43	276.92	289.33	126.07	726.29	2,413.04
Increase Coho 15%	10a	991.88	275.69	288.26	130.46	734.24	2,420.54
Decrease Coho 15%	10b	994.02	276.82	289.03	126.11	735.76	2,421.73
Increase King 15%	11a	992.97	277.32	288.49	130.77	736.89	2,426.44
Decrease King 15%	11b	993.94	276.81	288.90	126.69	732.94	2,419.27
Planned Production	2	955.09	296.22	274.52	157.15	713.85	2,396.84
Eliminate Program	3	1,109.59	288.91	309.48	144.29	863.69	2,715.95
Increase all 15%	4a	978.03	274.76	277.56	114.16	674.43	2,318.94
Decrease all 15%	4b	1,005.97	278.71	288.60	145.08	736.28	2,454.63

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

Change in Net Benefits of Production Alternatives for the Salmon Enhancement Program



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

A BENEFIT-COST ANALYSIS OF THE ALASKA SALMON ENHANCEMENT PROGRAM

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prepared as part of the

**Alaska Senate Special Committee on
Domestic and International Commercial Fisheries
Review of the Alaska Salmon Enhancement Program**

Final Report

December 1992

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

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Chapter I.

EXECUTIVE SUMMARY

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

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

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

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

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

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

The economics study consisted of four parts. First, a biological model (Collie, 1992) was used to estimate the returns of catchable fish under a variety of scenarios. Second, given the return of fish, an international demand model was estimated to predict the prices fishermen would receive at the ex-vessel level (Herrmann and Greenberg, 1992). Third, a fishing cost model was estimated to predict the producers' surplus in each fishery given the

ex-vessel prices and returns of fish from the biological model (Boyce, 1992)¹. Finally, a survey of the hatcheries revealed the costs of producing various levels of hatchery fish.

Research Objectives and Methodology

The request for proposals outlined 17 alternatives. These production alternatives are described in the first column of Table One. Each alternative was to be considered over a 30-year planning horizon. Given the trends in demand and supply suggested by the events over the past several decades, we have a rough idea of the direction in which the fishery is heading. Our estimates are likely to be very inaccurate within particular years, but should, on average, capture the trend. Since we were asked to conduct a cost-benefit analysis of the hatchery program over a long lifetime, the trend will be much more important than specific yearly predictions.

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

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

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

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

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

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

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

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

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

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

Comparison of Alternatives

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

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

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

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

If revenues rise because a price increase more than offsets a decrease in catch, then along with the increase in revenues will be a decrease in costs. This is superior to a case where revenues increase, but costs also increase, say due to the increase in catch more than offsetting the corresponding decrease in price. These examples suggest that net benefits to fishermen as measured by producers' surplus is a better measure of fishermen's welfare than changes in gross revenues.

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

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

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

Under current enhancement levels, the present value of returns to the state from the commercial salmon fishery is estimated to be \$2,423.1 million over 30 years. Looked at from a statewide perspective, two alternatives dominate Table 1. They are the elimination of the entire enhancement program (case 3) and the elimination of the pink salmon enhancement program (case 5). If the entire program was to be eliminated, our estimate is returns to the state of \$2,716.0 m, or an increase over current returns equal to \$293 million in present value, an amount equivalent to an annuity of \$16.3 million per year over returns from current levels. (Recall, however, that there are potentially serious problems with the case 3 simulations.) If the pink salmon program is eliminated, the state would earn a return of \$2,570.4 million in present value over the 30-year planning horizon. This is a difference of \$147.4 million for the 30 years, or equivalent to an annuity of \$8.2 million.

²This data is contained in the full report.

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

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

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

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

Costs and Benefits per Pound

Table 3 compares the statewide cost per pound of production with the statewide average producers' surplus (benefit) per pound. For pink salmon, the cost per pound for an increase of 15% (case 7a) is seven cents per pound. However, the additional producers' surplus is seven cents per pound, for a net loss of 14 cents per pound produced.

Statewide, enhanced red salmon costs an average of 40 cents per pound to produce, but produces only 14 cents per pound in producers' surplus, for a net loss of 32 cents per pound produced.

Chum salmon costs 10 cents per pound on average statewide to produce. It is estimated to produce 10 cents in producers' surplus, for no net gain.

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

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

Discussion of Findings

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

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

One significant caveat needs to be mentioned. While it appears that a reduction in enhanced fish would be warranted from an economic point of view, it does not follow that all hatcheries should be forced to shut down. However, *if a region wants to continue with a hatchery program, the most cost effective and marketable production level and composition would result if the program were entirely funded by the local user groups rather than subsidized by the state.* If the fishermen and facilities themselves fund the hatchery program, they will only choose projects which are cost-effective within their own region. There may still be regional effects in that production in one region causes prices to decline elsewhere, but whatever hatchery production remains will be cost effective.

If the state reduces or discontinues funding of the enhancement program, production of fish for sport and subsistence purposes will most likely not continue without some state funding. We have made no effort to analyze the net benefits from hatchery production on other user groups. To estimate more fully the benefits and costs to other user groups, the state would have to determine the net benefits to those groups.

There also may be strategic reasons for maintaining hatchery production. For example, it appears that hatchery exports of pink salmon may be starting in the former Soviet Union. Chile also appears to have room for expansion of its farmed salmon program. If these countries are able to produce fish less expensively than Alaska, then there will be no way to stop them from entering the market in the long run. However, by maintaining some hatchery production, prices may remain sufficiently depressed to prevent expansion in those areas. As long as the price is not driven down

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

to the level that it would reach if these other producers do enter the market, the hatchery dollars may be well spent. However, this is not a strategy which can remain viable over the long run.

Finally, let us emphasize that our estimates of net benefit are based on parameters estimated from relatively short time periods and were extrapolated well beyond the time horizon for which accurate estimates may be obtained. There are also a number of exogenous factors, such as what is happening in the rest of the salmon suppliers' markets, that have changed far too rapidly over the last decade to allow precise estimates of where the industry will be in one, two or three decades.

In spite of this, scaling back the enhancement program, and especially the pink salmon program, would increase net benefits.

Table One: Statewide Summary By Alternative

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

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

Table Two: Regional Net Benefits by Enhancement Alternative

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

ALTERNATIVE	WESTER N ALASKA	COOK INLET	KODIAK	PRINCE WM SD	SOUTH EAST	STATE TOTAL
(1) <i>Maintain current hatchery production</i>	993.40	276.55	288.69	126.63	737.78	2423.05
(5) <i>Eliminate pink salmon production</i>	1016.91	271.01	312.64	95.02	874.81	2570.39
(6) <i>Eliminate red salmon production</i>	1036.43	284.07	258.72	119.11	754.07	2452.41
(7a) <i>Increase pink salmon production by 15%</i>	990.19	277.31	281.15	116.59	712.88	2378.12
(7b) <i>Decrease pink salmon production by 15%</i>	996.61	276.73	293.54	131.11	758.86	2456.85
(8a) <i>Increase red salmon production by 15%</i>	987.77	276.36	292.62	126.74	724.09	2407.57
(8b) <i>Decrease red salmon production by 15%</i>	999.17	277.54	284.79	126.65	740.23	2428.38
(9a) <i>Increase chum salmon production by 15%</i>	992.53	276.15	286.22	123.13	736.14	2414.18
(9b) <i>Decrease chum salmon production by 15%</i>	994.43	276.92	289.33	126.07	726.29	2413.04
(10a) <i>Increase coho salmon production by 15%</i>	991.88	275.69	288.26	130.46	734.24	2420.54
(10b) <i>Decrease coho salmon production by 15%</i>	994.02	276.82	289.03	126.11	735.76	2421.73
(11a) <i>Increase king salmon production by 15%</i>	.97	277.32	288.49	130.77	736.89	2426.44
(11b) <i>Decrease king salmon production by 15%</i>	.94	276.81	288.90	126.69	732.94	2419.27
(2) <i>Planned hatchery salmon production levels</i>	955.09	296.22	274.52	157.15	713.85	2396.84
(3) <i>Eliminate entire salmon hatchery program</i>	1109.59	288.91	309.48	144.29	863.69	2715.95
(4a) <i>Increase entire hatchery production by 15%</i>	978.03	274.76	277.56	114.16	674.43	2318.94
(4b) <i>Decrease entire hatchery production by 15%</i>	1005.97	278.71	288.60	145.08	736.28	2454.63

Table Three: Enhancement Cost and Benefits per Pound

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

Chapter II.

INTRODUCTION

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

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

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

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

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

Scope of the Research

This analysis uses a state accounting stance, which means that, as far as possible, only the benefits and costs occurring in Alaska are considered. Thus, for example, the benefits to consumers in

other parts of the U.S. or in other world markets were not considered. This does not imply that these benefits do not exist, but recognizes that they are not captured by the state of Alaska.⁴

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

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

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

Research objectives

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

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

Table 1: The Alternatives Considered in the Policy Analysis

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

For each alternative, we report the 30-year projections for catch, revenues, producers' surplus, hatchery costs, and net benefits. All dollar figures are expressed in 1992 dollars. We discount future values at 4% discount rate.⁵ For each alternative, we report projections for 1) Western Alaska (Bristol Bay, the Aleutian islands, and AYK, which is the part of the state with little or no enhancement program), and for 2) Cook Inlet, 3) Kodiak, 4) Prince William Sound, and 5) Southeast Alaska. We also report state totals.

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

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

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

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

Research Methods

The research consisted of five parts:

- SALMON POPULATION AND EXPLOITATION MODEL: estimated the quantity of harvestable fish given enhancement production levels,
- INTERNATIONAL SALMON DEMAND MODEL: estimated prices and revenues given the biological model's projections of harvestable fish and assumptions about worldwide production and demand changes,
- COMMERCIAL SALMON FISHING COST MODEL: estimated the net returns to fishermen given the quantity and revenues attainable on the catchable fish,
- SALMON ENHANCEMENT COSTS: used hatchery operators' estimates of the costs to produce the enhanced production levels, and
- SALMON ENHANCEMENT SIMULATION MODEL: summarized the effects of each of the previous four models.

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

Benefits were measured primarily by two variables. First, we were interested in the net benefits to fishermen from the salmon enhancement program. That is, we wanted to estimate the return above

⁶It is inappropriate to simply view the cost part of the revenues as benefits because they represent expenditures to the other sectors of the state. While it is true that they represent expenditures to other sectors, they also represent what was foregone by the fishermen if they had been engaged in their next best alternative.

fishermens' costs. These net benefits were estimated under different assumptions regarding salmon enhancement production output levels. Second, the cost of producing these benefits to the fishermen is the cost of running the enhancement program. These costs include enhancement facility costs, as well as Department of Fish and Game administrative support and management costs.

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

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

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

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

Modeling Assumptions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Technical Limitations of the Models

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

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

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

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

Even though we predict high, mid, and low prices, we are still comparing revenue cases against the base cases for average vs. average prices, high vs. high prices, and low vs. low prices. In addition, our predictions of total revenues and producers' surplus are missing confidence levels which would probably make some of the differences between alternatives insignificant.

- **The production levels under each of the elimination alternatives are vastly different than the production levels we observed in the historical time period used to estimate our demand and fishing cost models.**

All of our estimation of demand and fishing cost parameters occurred with hatchery and production figures that were considerably higher than the levels considered in cases 3, 5 and 6 (Table 1). It is less true for case 6 because enhancement production of red salmon is small relative to the total quantity of red salmon. However, it is particularly true for cases 3 and 5, which involve drastic

reductions in the pink salmon catches. Because of this, we are forced to extrapolate well beyond the data in our analysis. The result of the extreme extrapolation may be to predict prices which are *above* their historical levels.⁷

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

It was necessary to aggregate Pacific salmon into high-valued (red, king, and coho) and low-valued salmon (chum and pink) in the demand side of the model. This was needed to simplify the number of specified species in order to estimate the model. However, because of this, there are no *empirical estimates* of cross-price effects between species within an aggregate grouping. As a result, ad hoc assignments to substitution effects between species within each aggregate grouping were made. For example, we assumed that the strength of the substitution effect between pink and chum salmon to be one-quarter (25%) of the strength imposed in the model, and vice versa. The assumed cross-price effects were kept fairly low in order to error on the side of conservatism.⁸ Similar assumptions were made for cross-price effects between species in the high-valued species aggregation. We do have empirical cross-price effects for effects of species within the low-valued grouping on species within the high-valued grouping, and vice versa. These are reported and discussed in the demand model report (Herrmann and Greenberg, 1992).

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

As a result, an accurate estimation of cases 2-4, where there were simultaneous changes in enhancement production, was not possible. Because the model imposed cross-price effect within the groupings may be overstated, the revenues assigned to cases 2, 3, and 4a may be understated, and the revenues for 4b may be overstated. For this reason, only cases 1 and 5-11, when the ad hoc cross-price effects within the aggregate salmon groupings can be imposed, offer realistic revenue forecasts. The losses found in cases 2, 3, and 4a should be viewed as worst cases scenarios, and 4b as a best case scenario. The results from each of these alternatives should be viewed with caution. Because we have less confidence in cases 2-4, these results have been segregated from the main body of the report and from the summary tables.

⁷This occurs with some extent to our predictions of pink salmon prices. If the pink salmon program is eliminated, we estimate pink prices to average about \$0.46 per pound ex-vessel. Over the period 1980 to 1991, nominal prices averaged only \$0.31 per pound, although in approximately one-third of the years the real 1992 dollars prices rose to this level. The two most recent cases, 1987 and 1988, are years for which pink salmon volumes were at their lowest over the period.

⁸We examined the results using the full cross-price effects. The result was that a decrease in pink salmon caused chum salmon revenues to increase dramatically. This made the effect of reducing the pink salmon program even less costly since there was a large compensation due to an increase in chum revenues. It appears that the relationship between chum and pink salmon is an issue which deserves more research.

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

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

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

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

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

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

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

In the extrapolation of the fishing cost model to future years, we took the 1990 run for the fishery as our guide to how the run would be dispersed over time and across the statistical areas within the fishery. If a future year showed an increase over the 1990 data for a particular species of, say, 10%, then we inflated the catch of that species by 10% for each opening over the season. Having

done this for each species, we then multiplied the estimated catch by the price per pound for each species. We then used the data on percentage by species of the catch and of total revenues per opening to make a prediction of the number of fishermen participating in each opening throughout the season using the parameters of our participation model estimated with 1990 data. To obtain our estimate of fishing costs for the opening, we utilized the relationship between average revenues and the number of fishermen and the behavioral assumption that the last fisherman to enter earned revenues equal to their fishing costs. The fishing costs for the entire opening were obtained by summing the fishing cost equation for each fisherman up to the estimated number of participants. The fishing costs for the season were simply the sum of these fishing costs over all of the openings. Producers' surplus was estimated as the difference between the fishing cost estimates and the revenue estimates.

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

One problem with our fishing cost model, which is consistent across all of the analyses of alternatives, is the problem of extrapolating cost data from one fishery to another. In particular, fishing costs were estimated for only a select number of fisheries. For all other fisheries, we used the *average* estimate of fishing costs for similar gear type fleets elsewhere in the state. This problem is particularly acute for Western Alaska. The main problem here occurs in the drift net fleet. The Bristol Bay drift net fleet is about 2,000 vessels strong. None of the other drift net fleets are anywhere near this size. Thus our estimates of producers' surplus in Western Alaska may be very inaccurate. However, the evidence from the other drift net fleets suggests that the drift net fleets are very similar. Producers' surplus was estimated to be around 14-15% of total revenues in each fleet. The estimated standard error of that estimate was $\pm 3\%$. The problem is simply that the extrapolation is for a fleet of more than double the size of the fleets for which explicit parameter estimates exist. One clue as to the direction of this error is in our estimates of the number participating for those fleets for which we have data. The estimates of the number of vessel days for the season are always less than the actual number.⁹ This means that our estimate of costs for the marginal fishermen may be overstated, understating the producers' surplus. This will tend to dampen the effect of alternatives that are favorable to the Western Alaska fleets such as cases 3, 5, and 6.

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

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

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

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

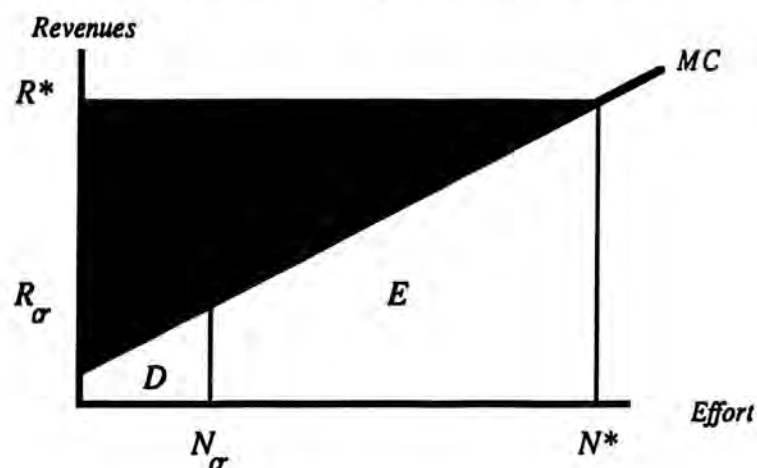
The analysis we were requested to undertake was only for the commercial fisheries. Therefore, enhancement costs associated with fish stocks used by other user groups was not considered. However, neither were the benefits to these groups considered. This is work which deserves further attention, but is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

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

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

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

Figure One: Net benefits calculation



Given that total revenues are such that an individual fisherman may earn revenues of R^* , there will be N^* fishermen who participate in the fishery. Thus total revenues is the area of the box with height R^* and width N^* , which has value R^*N^* . The total fishing costs associated with earning revenues R^*N^* is the area under the opportunity cost function, MC, represented by the areas labeled D and E. The area above the MC line (areas A, B, and C) represents producers' surplus. Total hatchery costs are the areas A, B, and D. Areas B and D represent the cost recovery costs. The area A represents the profits the hatchery makes on the cost recovery, but these profits are

used to pay for the hatchery costs. The cost recovery costs B and D are costs to the hatchery, but revenues to the N_{CR} fishermen who participate in the cost recovery. The area D represents the costs to the N_{CR} fishermen participating in the cost recovery, B is their producers' surplus. Thus the net benefits to fishermen after hatchery costs are accounted for is areas B and C . Area A is producers' surplus that is captured by the hatcheries, but goes to paying for the enhancement costs.

Chapter III.

RESULTS

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

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

Differences in Catch among the Alternatives

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

Table 2: Total Commercial Catch by Enhancement Alternative

(millions of pounds, 30 year sum)

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

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

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

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

Differences in total revenues among the alternatives

Proportional increases in catch do not imply proportional increases in gross revenues. (It should be noted that this section discusses gross revenues, and not net benefits, of enhanced production.) Revenues depend upon both quantities and prices. Since increases in quantities cause prices to decrease, revenues may either increase or decrease as quantities decrease. A much more thorough discussion of the revenue effects is contained in the discussion of the demand model (Herrmann and Greenberg, 1992). However, a summary of the revenue differences between the alternatives is contained in Table Three. Cases 2-4 have been separated from the rest to emphasize that these estimates are less accurate than those for cases 1 and 5-11.

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

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

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

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

Table 3: Gross Revenues by Enhancement Alternative

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

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

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

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

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

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

Cases 4a and 4b emphasize this point well. These are the cases where enhancement output is to increase or decrease by 15% for all species simultaneously. Aside from the fact that it would never make economic sense to follow such a policy unless each species contributed exactly the same marginal return, the results show how the demand model got "confused" by the simultaneity of the changes in enhancement production levels. First, *both* an increase and a decrease of 15% of all species simultaneously caused statewide revenues to decrease relative to the current output levels. Secondly, the direction of the effects is quite different across regions. Western Alaska appears to respond reasonably, with an increase in enhancement production for all species causing revenues to decline, and a decrease causing revenues to increase. Conversely, both Prince William Sound and Cook Inlet show increases in revenues with an increase in enhancement production and decreases in total revenues with decreases in enhancement production. This is presumably because they are the major producers of enhanced fish. The results are less clear for Kodiak and for Southeast. In each case, these regions end up with a decrease in revenues relative to current enhancement output levels. Thus the aggregate reduction in revenues from these two cases cannot be explained by differential regional effects alone.

Differences in Producers' Surplus among the Alternatives

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

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

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

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

Table 4: Producers' Surplus by Enhancement Alternative

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

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

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

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

While a 15% increase (decrease) of chum, coho, or king causes an increase (decrease) in statewide producers' surplus, the magnitude is quite small and not likely to be significant. The effects of 15% increases or decreases in pink and red salmon are more noticeable (though we cannot say whether they are statistically significant). The changes in producers' surplus for pink and red salmon increases and decreases are similar in sign to the effect of changes in revenues. More pink salmon helps Prince William Sound and Cook Inlet, and more red salmon helps those two regions plus Kodiak. Both Western Alaska and Southeast have reductions (increases) in producers' surplus from increases (decreases) of either pink or red salmon.

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

Enhancement Costs under the Different Alternatives

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

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

Table 5: Enhancement Costs by Enhancement Alternative

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

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
1	0.00	34.80	28.69	185.17	171.56	420.22
5	0.00	24.94	22.05	103.23	156.44	306.65
6	0.00	13.40	18.77	157.20	156.75	346.12
7a	0.00	34.93	31.90	200.59	176.50	443.91
7b	0.00	33.32	27.69	172.88	169.29	403.18
8a	0.00	37.33	29.93	188.92	184.95	441.13
8b	0.00	31.59	27.20	180.97	169.34	409.10
9a	0.00	34.80	31.16	189.46	187.89	443.31
9b	0.00	34.80	27.92	184.62	167.26	414.59
10a	0.00	35.60	29.02	181.98	180.11	426.73
10b	0.00	34.48	28.49	185.08	168.35	416.40
11a	0.00	34.00	28.69	181.14	179.28	423.11
11b	0.00	34.48	28.69	185.09	169.62	417.87
2	0.00	36.05	28.69	195.05	179.75	439.54
3	0.00	1.78	1.38	6.18	8.58	17.93
4a	0.00	37.47	35.95	201.43	222.53	497.38
4b	0.00	29.48	25.24	167.96	157.61	380.29

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

All cost data represent facility operators' estimates of costs under the various alternatives. There is reason to believe that the costs may be overstated for a number of the reduction scenarios. For example, the cost savings from elimination of the pink program is \$113.6 million or about a 27% reduction. Cost savings from elimination of the red salmon program result in a reduction of \$37.5 million, or a savings of 8.9%. Thus, elimination of the two largest programs reduces costs by less than 40% according to the operators. This appears to imply that there are costs which must be incurred whether production of a particular species occurs or not. The only way to eliminate those costs appears to be to close the entire facility. It is likely that faced with such an option, other cost savings would appear.

Net Benefits under the Different Alternatives

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

Under current enhancement levels, the present value of returns to the state from the commercial salmon fishery is estimated to be \$2,423.1 million over 30 years. Looked at from a statewide perspective, two alternatives dominate Table 6. They are the elimination of the entire enhancement program alternative (case 3) and the elimination of the pink salmon enhancement program (case 5). If the entire program were to be eliminated, our estimate is a return to the state of \$2,716.0 million, or an increase over current returns equal to \$293 million in present value, or equivalent to an annuity of \$16.3 million per year over returns from current levels. Recall, however, that there are potentially serious problems with the case 3 simulations. If the pink salmon program is eliminated, the state would earn a return of \$2,570.4 million in present value over the 30-year planning horizon. This is a difference of \$147.4 million for the 30 years, or equivalent to an annuity of \$8.2 million.

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

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

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

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

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

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

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

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

Chapter IV.

FURTHER ANALYSIS

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

Per Pound Costs and Benefits of Salmon Enhancement

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

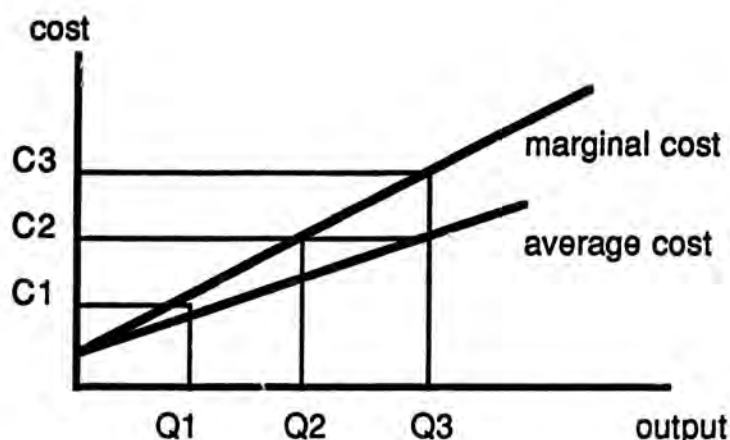
However, it is likely that this survey procedure understated the cost of producing enhanced fish stocks. This point is shown in Figure Two, using three different levels of fish production or output. The marginal cost line measures the cost of an additional unit of output. For example, the cost of the output Q1 is C1. If output were to be increased to Q2, then the cost of the Q2 unit would be C2. The average cost if Q2 is produced would be the mean of C1 and C2. Since the average cost includes units of output that have lower marginal costs, the average cost is less than the marginal cost.

The analysis of the potential effects of elimination of all or parts of the enhancement program reveals some interesting information about the cost per pound of enhanced fish production. Eliminating the pink salmon program reduces the estimated catch over 30 years by 3.880 billion pounds and reduces enhancement costs by \$ 191.0 million in *undiscounted* 1992 dollars over the 30-year planning horizon.¹³ Thus, the cost per pound of the pink enhancement program is approximately 5 cents per pound.

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

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

Figure Two: Marginal and average hatchery costs



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

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

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

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

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

Statewide, enhanced red salmon costs an average of 40 cents per pound to produce, but produces only 14 cents per pound in producers' surplus, for a net loss of 32 cents per pound produced.

Chum salmon costs ten cents per pound on average statewide to produce. It is estimated to produce ten cents in producers' surplus, for no net gain.

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

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

Sensitivity Analysis: High and Low Price Predictions

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

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

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

Table 8: Sensitivity Analysis for Selected Enhancement Alternatives

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

CASE	WESTERN ALASKA	COOK INLET	KODIAK	PRINCE WILLIAM SOUND	SOUTHEAST	STATE-WIDE TOTAL
<i>Case 1: current levels</i>						
low	886.98	247.07	255.36	102.32	672.83	2164.56
mid	993.40	276.55	288.69	126.63	737.78	2423.05
high	1173.08	325.67	341.24	162.96	836.48	2839.43
<i>Case 2: planned levels</i>						
low	854.67	264.76	242.79	127.14	650.14	2139.50
mid	955.09	296.22	274.52	157.15	713.85	2396.84
high	1124.57	348.88	324.67	201.84	809.71	2809.67
<i>Case 3: eliminate all salmon enhancement</i>						
mid	1109.59	288.91	309.48	144.29	863.69	2715.95
high	1317.74	337.80	357.21	164.53	958.78	3136.05
<i>Case 4a: increase all enhancement by 15%</i>						
mid	978.03	274.76	277.56	114.16	674.43	2318.94
high	1154.19	324.06	330.28	151.70	772.33	2732.56
<i>Case 4b: decrease all enhancement by 15%</i>						
low	873.69	281.13	278.24	284.53	823.87	2541.47
mid	1005.97	278.71	288.60	145.08	736.28	2454.63
high	1188.75	327.79	340.19	180.84	832.95	2870.51
<i>Case 5: eliminate all pink enhancement</i>						
mid	1016.91	271.01	312.64	95.02	874.81	2570.39
high	1200.71	319.92	366.87	123.08	983.00	2993.58
<i>Case 6: eliminate all red enhancement</i>						
low	923.13	231.62	213.91	55.60	624.41	2048.67
mid	1036.43	262.67	253.90	94.83	767.95	2415.79
high	1209.47	328.45	301.76	143.42	818.05	2801.15

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

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

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

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

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

We suspect that this result is due to two factors. First, 4b has the most drastic reduction for which the demand model could be made to converge. Under this scenario, pink salmon prices are predicted to reach record high levels. Under the low-price scenario, factors which in general contribute to low prices were inflated, and factors which generally contribute to high prices were deflated. However, factors that contribute to high prices of the high-valued species are not necessarily factors which contribute to high prices for low-valued species. We suspect that the

combination of these two effects lead to the result that alternative 4b has such a large positive return to Prince William Sound and to Southeast under the low-price scenario. Since this case, along with all of the cases 2-4, are subject to the limitations we discussed in section I, this result should be viewed with caution.

Sensitivity Analysis: Effect of the Discount Rate

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

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

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

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

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

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

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

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

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

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

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

Chapter V.

DISCUSSION OF FINDINGS

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

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

One significant caveat needs to be mentioned. While it appears that a reduction in enhanced fish would be warranted from an economic point of view, it does not follow that all hatcheries should be forced to shut down. However, *if a region wants to continue with a hatchery program, the most cost effective and marketable production level and composition would result if the program were entirely funded by the local user groups rather than subsidized by the state.* If the fishermen and facilities themselves fund the hatchery program, they will only choose projects which are cost-effective within their own region. There may still be regional effects in that production in one region causes prices to decline elsewhere, but whatever hatchery production remains will be cost effective.

If the state reduces or discontinues funding of the enhancement program, production of fish for sport and subsistence purposes will most likely not continue without some state funding. We have made no effort to analyze the net benefits from hatchery production on other user groups. To estimate more fully the benefits and costs to other user groups, the state would have to determine the net benefits to those groups.

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

Finally, let us emphasize that our estimates of net benefit are based on parameters estimated from relatively short time periods and were extrapolated well beyond the time horizon for which accurate estimates may be obtained. There are also a number of exogenous factors, such as what is

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

happening in the rest of the salmon suppliers' markets, that have changed far too rapidly over the last decade to allow precise estimates of where the industry will be in one, two or three decades.

In spite of this, scaling back the enhancement program, and especially the pink salmon program, would increase net benefits.

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**LEGISLATIVE
REVIEW
OF
ALASKA'S
SALMON ENHANCEMENT
PROGRAM**

February 1992 ~~ Draft Report

DRAFT REPORT ** DRAFT REPORT ** DRAFT REPORT

**LEGISLATIVE REVIEW OF ALASKA'S FISHERIES
ENHANCEMENT PROGRAM**

February 10, 1992

Executive Summary & Options to Consider

- I. Introduction
- II. History & Development of Hatcheries in Alaska
- III. Production Policies and Trends in Alaska and Worldwide
- IV. Fisheries Management Issues
 - A. Mixed-Stock Fishery Management
 - B. Quality
 - C. Tagging Needs
- V. Legal Issues Raised by Board of Fisheries
- VI. Planning and Permitting Process
- VII. Biological Issues
- VIII. Enhancement Funding
- IX. Economics
- X. Marketing
- XI. Other Issues
 - A. Use of Hatcheries as Environmental Mitigation
 - B. Role of Hatcheries in International Treaties
 - C. Environmental Regulations
 - D. Use of Hatcheries as Tool for Economic Development
 - E. Importance of Hatcheries to Sport Fish
 - F. Contribution to Subsistence Fish
 - G. Enhancement of Other Species

Exec.

Summary/

Options



Alaska State Legislature

Official Business

SENATE SPECIAL COMMITTEE
ON DOMESTIC AND INTERNATIONAL FISHERIES

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

February 10, 1992

Dear Reviewer:

Attached is the Executive Summary of the Draft Report of the Legislative Review of the Alaska Salmon Enhancement Program which is being released today for public comment by the Senate Special Committee on Domestic and International Fisheries.

Many issues and concerns relating to the state's salmon enhancement programs have been brought to the Legislature's attention over the last few years. Last spring it became apparent that it was time the Legislature, as the state policy-setting body, step back and take a broad look at these programs. The Committee decided to undertake this review with the participation of all interested Alaskans.

I must strongly emphasize that this report is only a DRAFT. It is the result of an effort to identify and research various issues, concerns and conflicts associated with the state's salmon enhancement program, and to begin laying out some possible options (not recommendations at this point) to consider for improving the program.

This draft report has been prepared by legislative staff with the assistance of the Legislative Research Agency and the input of state agencies and others. It is a starting point. Now it is time to enlist the help, and incorporate the suggestions, of other legislators, hatchery operators, fishermen, scientists, processors and others who care about the state's enhancement programs.

It should be noted that one important segment of the review is missing. That is the economic analysis that was contracted to professional researchers at the University of Alaska. This analysis will not be complete and available for several months. Therefore, this draft report contains information gathered on other aspects of the program, with specific options presented at the end of each chapter. Until the economic studies are incorporated into the entire review, we cannot presume to be looking at the "whole picture." When that last major piece of the puzzle is in place, we will begin the process of formulating some overall conclusions.

Our goal now is to fine-tune the chapters contained in this draft report, see what conclusions can be reached with the information before us, and develop those options which we can act on right away. We are counting on your comments on the contents of this

draft report, especially regarding your thoughts about the lists of options: which ideas you like or dislike; which ones should be addressed immediately, and how; what additional options should be added to the list for consideration. Please let us know of any errors, omissions, or misinterpretations you see in this draft.

We urge you to participate in a teleconferenced hearing on this report scheduled for Monday, February 24, from 1:30 to 5:00 p.m. This will be the first of several hearings on the various aspects of the enhancement program and any legislative action that may be proposed. In addition to your testimony at the teleconference, it would be helpful to have your comments in writing as soon as possible. (To: Sen. Eliason, Senate Fisheries Committee, State Capitol, Juneau, AK 99801-1182, or to FAX #907-465-4928). Public input is vital to the success of this review!

Please note that what we are sending out is the executive summary of the draft report which includes the lists of possible options for consideration at the end of each chapter, and a table of contents for the full report. The complete draft report is several inches thick. If you would like to receive a copy of any particular chapter(s), please call my office at 465-4916, or check with your local Legislative Information Office as we will be sending a complete draft report to most LIOs to have available to the public.

Thank you for your interest in this review project, and for any ideas and input you can contribute. We look forward to working with you.

Sincerely,

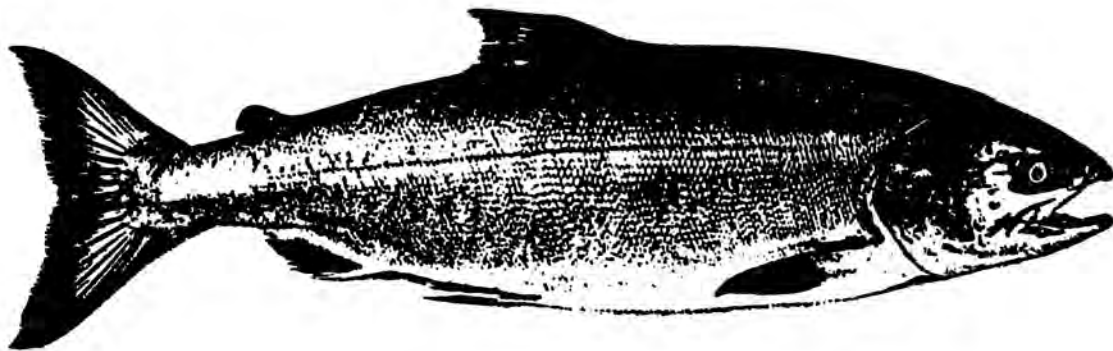


Senator Dick Eliason, Chairman
Senate Special Committee on
Domestic and International Fisheries

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

EXECUTIVE SUMMARY



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

February 10, 1992 new date

Chapter I

INTRODUCTION

In the late spring of 1991, the Alaska Senate's Special Committee on Domestic and International Commercial Fisheries initiated a review of salmon fisheries enhancement in Alaska. The committee recognized that while hatchery and other enhancement projects in Alaska have been highly successful, they have not been comprehensively reviewed since the program's inception nearly 20 years ago. Since the program was initiated by the Alaska Legislature, and setting policy for state programs is a legislative responsibility, it is appropriate that the Legislature be the entity to conduct this review.

The committee began its work with no pre-conceived notions regarding its eventual findings and conclusions. Rather, legislative staff were directed first to compile relevant information, question interest groups, and develop a series of recommendations or options for action that could be taken to improve the state's program. This review is to serve as a starting point for a process of scrutiny and fine-tuning that may become an established part of the enhancement program itself.

It should be noted that an important segment of the review is not included in this draft report. The economic analyses, contracted to professional researchers, will not be complete and available for several months. Therefore, this draft contains information on the other topics of the review, with options presented at the end of each chapter regarding that specific chapter. Overall conclusions regarding Alaska's salmon enhancement program will be developed after the economic studies have been completed and analyzed in relationship to the information contained in this draft report.

Chapter II

HISTORY AND DEVELOPMENT OF HATCHERIES IN ALASKA

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

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

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

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

- creation of the Division of Fisheries Rehabilitation, Enhancement and Development (FRED) within the Alaska Department of Fish and Game,
- passage of a number of bond issues authorizing tens of millions of dollars for capital improvements for state hatchery facilities,
- authorization of private nonprofit (PNP) corporation hatcheries, and
- creation of regional aquaculture associations (as PNP) responsible for the regional planning and coordination of salmon enhancement activities.

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

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

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

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

A review of legislative history reveals that many facets of the hatchery program which have evolved over the past two decades, such as financing, related fisheries management issues, and biological concerns, were not foreseen or were only briefly acknowledged or discussed by the Legislature during the initial stages of development of the program. The record does reveal legislative intent in some broad areas, but it appears that many current questions and concerns

regarding the role and future of hatcheries will have to be addressed without benefit of clear statutory or historical direction.

Chapter III

PRODUCTION POLICIES AND TRENDS IN ALASKA AND WORLDWIDE

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

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

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

CHAPTER IV

FISHERIES MANAGEMENT

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

MIXED-STOCK FISHERIES

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

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

QUALITY

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

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

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

TAGGING NEEDS

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

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

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

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

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

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

OPTIONS FOR POSSIBLE CONSIDERATION:

- Development of a state policy on managing mixed-stock fisheries composed of hatchery and wild stocks.
- Requiring hatchery production to have tagging, recovery and analysis programs. This could range from a blanket requirement for all production to site-specific requirements.
- Development of a policy regarding funding for tagging, recovery, processing and analysis.
- Funding a study to analyze salmon quality at various distances from terminal streams to determine the effect of fishery management effort on product quality and marketability.

- Direction to the Board of Fisheries on how to factor managing for quality into fisheries management plans.
- Funding research and development of new tagging and marking techniques suitable for mass marking.
- Clarifying the roles and uses of tagging---for biological information, allocation, or management purposes.
- Expanding tagging and stock identification studies of wild fish stocks for the purpose of comparing wild and hatchery stocks.

Chapter V

LEGAL ISSUES RAISED BY BOARD OF FISHERIES

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

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

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

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

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

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

ATTORNEY GENERAL OPINION

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

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

OPINION RESPONSES

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

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

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

The second opinion that questioned assistant attorney general White's conclusions was from Legislative Counsel George Utermohle, in an April 8, 1991 letter to Senator Dick Eliason. He argues that, if the legislature had intended for hatchery fish to be managed on a sustained yield basis, it would have used the phrase "belonging to the state" when it wrote AS 16.10.440(a), quoted above. Utermohle reasons that the legislature intended hatchery fish to be treated as if they were a part of the common property resource, but only until they return to the designated harvest location; at that point, the hatchery operator may harvest the fish. Utermohle asserts that this language "suggests some form of lingering private property interest in hatchery fish by the hatchery operator," and indicates that the fish do not "belong" to the state for purposes of sustained yield.

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

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

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

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

Saupe also points to "an extensive web of statutory provisions that evidence an unwavering legislative intent to sustain and expand hatchery operations through hatchery harvest," as evidence of the legislature's belief that harvests are necessary and beneficial. Among these provisions: AS 16.10.443, which requires the department to assist permit holders in the operation of their hatcheries; AS 16.10.450(a), which contains certain expenditure requirements for hatcheries that sell salmon or salmon eggs after harvest; AS 16.43.420, which allows for the sale of fish caught under the authority of a special harvest area entry permit; and AS 16.10.430(b), which allows sale, but not release, of fish during the period

of time that a hatchery operation is being terminated; AS 16.05 020, which requires the commissioner to "improve and extend" the fisheries of the state. Saupe concludes that the cited statutes, and legislative history, demonstrate the legislature's intention that cost-recovery harvests be the primary method of funding private nonprofit hatchery operations.

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

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

CONCLUSIONS

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

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

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

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

OPTIONS FOR POSSIBLE CONSIDERATION:

- Placing a wild stock priority into state statutes; or alternatively, making the status of wild and hatchery stocks of equal priority, or leaving the statutes ambiguous.
- Clarifying in state statutes whether or not the Board of Fisheries is required to provide for hatchery broodstock or for cost-recovery fisheries.
- Clarifying the Board of Fisheries' authority to restrict hatchery production.

Chapter VI

PLANNING AND PERMITTING PROCESS

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

CURRENT PLANNING AND PERMITTING PROCESS

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

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

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

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

Fish released by hatchery operators are available for common use as natural stocks, until they return to the location established by the department for hatchery harvest. The Board of Fisheries may, after a permit has been issued, amend by regulation the terms of the permit relating to the source and number of eggs, the harvest by hatchery operators, and the locations of hatchery special harvest areas. This is the basis for the board-regulated Fish Transport Permit process (see Biological Issues chapter), establishment of hatchery special harvest areas, and board-approved terminal harvest area plans. The statutes also appear to give the Board the authority to limit or control production at individual hatcheries based on egg-take for broodstock. This authority has never been used, and there is a strong difference in opinion as to whether or not the Legislature

actually intended the Board of Fisheries to regulate hatchery production, or instead, to regulate the taking of eggs from wild stocks for hatchery production.

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

FISH TRANSPORT PERMITS

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

FISH RESOURCE PERMITS

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

PROBLEMS AND ISSUES

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

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

2. Regional v. Statewide Planning.

State law directs salmon production planning to be done on a regional basis. Little comprehensive statewide planning is done, with only minimal interaction between regions

of the state. At the time these provisions were enacted, it was not envisioned that hatchery-produced fish would become such a large proportion of the statewide harvest. *Fisheries managers argue that the state needs a statewide planning policy that will take into account the potential impacts of the production of one region on another, as well as closely scrutinizing potential management problems and marketing feasibility. Others involved in the industry argue that regional differences are so unique and contentious, that such a statewide process would be futile.*

The Board of Directors of the United Fishermen of Alaska (UFA) in January 1992, requested the FRED Division to involve all RPTs in a statewide review process of hatchery production.

3. Funding and support for planning.

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

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

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

4. Composition of Regional Planning Teams

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

Another, more fundamental concern is that ADF&G managers are usually out-numbered on the RPTs. As a result, the group can pressure department managers into approving projects that should probably be denied. Department personnel who raise future management concerns are under considerable pressure to be a *positive* presence in the

RPT process, which in some cases, translates into withdrawing or modifying their objections without these concerns being adequately addressed. On the other hand, concern has also been expressed that department managers sometimes have a strong, anti-hatchery bias that can influence their management recommendations.

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

5. Allocation issues.

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

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

6. Management issues.

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

7. Uniform review.

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

8. Criteria to show public benefit.

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

- the contribution the proposed hatchery would make to the common property fishery,
- the provisions for protecting wild stocks from any adverse effects which may originate from the proposed hatchery,
- the compatibility of the proposed hatchery with the goals and objectives of the comprehensive salmon plan for the region, and
- whether the proposed hatchery would make the best use of the site's potential to benefit the common property fishery.

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

9. Operation performance reviews and permit revocation.

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

10. Hatchery Siting Privileges

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

11. Canadian evaluation model.

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

OPTIONS FOR POSSIBLE CONSIDERATION:

- Working with the public and user groups to develop statewide goals and objectives for the state's entire fisheries enhancement program.
- Directing FRED Division to develop a program to implement these goals and objectives.
- Declaring a moratorium on further hatchery development or increased production until the Legislature's economic cost-benefit studies are complete and a full assessment of the hatchery program can be made.
- Development of a statewide planning process.
- Development of a statewide production plan.
- Requiring FRED to develop a comprehensive annual report that not only compiles production figures from state and PNP facilities, projects, and current management regimes, but also includes future production and management plans.
- Evaluation of the composition and procedures of the RPT to determine if changes in the RPT structure are necessary.
- Expansion of state statutes to require all hatcheries, including state facilities, to comply with a single planning and permitting process, with the same requirements for monitoring and review.
- Widening the scope of RPT review, including recommendations for allocation of enhancement production.
- Providing adequate funding for planning.
- Reviewing the required Management Feasibility Analysis to determine if it needs to be a more comprehensive review.
- As part of permit review and solicitation of state loans, consideration of adding new criteria to show public benefit, including marketability, a detailed cost/benefit analysis instead of a financial feasibility analysis, a more specific indication of the "significant contribution" to be made to the common property fishery, and some kind of environmental assessment.
- Providing concrete direction for the timely performance review of PNP hatcheries and a more workable mechanism for closing or converting hatcheries not making a "significant" contribution to the common property fishery.
- Exempting the alteration, suspension or revocation of an enhancement permit for violations from the Administrative Procedures Act.
- Instituting a regular review process similar to the Canadian model.
- Clarifying Board of Fisheries authority to regulate hatchery production levels.

- Re-evaluation of the policy of giving regional aquaculture associations the preference rights to develop future hatchery sites in the region.

Chapter VII

BIOLOGICAL/GENETIC ISSUES

In November 1991, in Cordova, Alaska, the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, convened a group of world-renowned experts to examine "The Biological Basis for Maintaining Strong Co-existing Stocks of Natural and Enhanced Salmon Populations in Alaska." This workshop followed a series of international symposiums on this topic during the past two years. Top fisheries biologists, ecologists and geneticists from the United States, Norway, Sweden, the Soviet Union and Japan were present at the Cordova workshop. As a follow-up to the workshop, the group intends to produce a summary report and list of recommended policies and procedures to be considered by the state of Alaska in managing its wild and enhanced salmon stocks. That report is expected in late February.

The cumulative effect of hydroelectric dams, habitat destruction, overfishing, and large-scale hatcheries has led to the decimation of many wild salmon stocks in Pacific Northwest states. Biologists in states with a long history of hatchery programs are generally less enthusiastic about these programs than biologists in areas such as Alaska and British Columbia with comparatively recent programs. *Although poor hatchery practices can clearly endanger wild salmon populations, scientists do not agree on the extent to which hatcheries with sound practices can co-exist with sustained healthy runs of wild salmon.*

The lack of consensus among scientists largely results from insufficient data and research, and at times, professional bias. Even where information exists, however, it is often subject to conflicting interpretations. To complicate matters, results of specific studies may not be transferable to other areas or salmon species, and year-to-year environmental changes may affect the results of these studies.

THE GENETIC EFFECTS OF HATCHERIES

Most scientists agree that it is essential to have healthy wild stocks to maintain the health and genetic diversity of both wild and hatchery stocks; genetic diversity must be preserved. Scientific knowledge about the genetic impact on wild stocks of hatchery fish, however, is still incomplete. Reduction in the fitness of salmon stocks, to the extent it has been documented, may involve numerous factors. Most scientists agree that hatcheries can complicate mixed-stock fisheries and affect the genetic composition of wild fish stocks. Scientists do not agree on the extent to which genetic changes affect the short- or long-run fitness of wild stocks.

Straying and intermingling of stocks is a major concern to scientists. The extent of straying, the variables involved in imprinting, and the effects of interbreeding are largely unknown. Large-scale ocean ranching appears to set the stage for straying of wild stocks in the harvest areas of enhanced stocks and also for hatchery fish to stray into the natural streams. What impact this has on the genetic diversity of salmon stocks in a given

region is a question that remains to be answered. However, the concern is that intermingling may reduce the fitness of the locally adapted populations.

It is known that the greater the distance between the donor stream or hatchery and the release site, the greater the amount of straying. Many scientists are concerned about the extensive releases at remote sites practiced by many hatchery operations today, with many more planned for the future. They fear that such straying could potentially, in time, destroy genetic diversity -- resulting in a permanent, irreversible loss. Some scientists believe remote releases should be banned altogether. Others believe they should be permitted with stringent controls and careful monitoring.

OCEAN CARRYING CAPACITY

Some scientists suspect that the carrying capacity of nearshore marine waters and the high seas for salmon may be exceeded by large-scale releases of hatchery salmon. A reduction in the average size of salmon was reported throughout the Pacific region in 1991, but various factors may be responsible. Since 95 percent of the growth of salmon occurs at sea, some researchers believe ocean conditions affect the size of salmon more than competition. Much evidence, however, supports the theory of density-dependent growth for some salmon species, although there is considerable debate regarding its occurrence. More information is needed on the effects of predation and competitors.

DISEASE

Few studies document the transmittal of diseases between hatchery and wild salmon, and there is no documentation of such transmittal in Alaska. Where transmittal of a disease by hatchery salmon has been documented, it occurred after fish were transplanted long distances. Hatchery fish appear to be more vulnerable to disease than wild fish because of the stress of hatchery conditions and large concentrations of eggs and fry. Norway has had considerable problems with disease transmitted by farmed salmon that have escaped and mixed with wild stocks.

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

STATE GENETICS PROGRAM AND POLICY

The state genetics program is intended to implement policies and procedures that protect and maintain the genetic uniqueness of Alaska's wild salmon stocks in the face of North America's largest salmon enhancement program. The state's fish genetics policy, considered to be one of the most stringent in the world, was last revised in 1985, and will be reexamined and updated this year.

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

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

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

The genetic policy also acknowledges that all salmon runs are not of equal importance. The effect of a salmon enhancement project depends to some degree on the relative value of the stock that might be impacted. However, the policy says that the concept of "significant stock" only relates to the size of a fish population in the context of local importance and use. A population that would be considered insignificant in size in one region, may be of vital importance in another region.

OPTIONS FOR POSSIBLE CONSIDERATION:

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

- Evaluation of how well the current hatchery program protects wild salmon from possible negative effects of hatchery salmon. Such a review would help policy makers determine the risk of various alternatives for the future of Alaska's hatchery program.
- Increasing the amount of genetic monitoring required of hatchery operators, and directing ADF&G to continuously review and analyze resulting data statewide.
- Obtaining consensus about research priorities concerning the interaction of hatchery and wild fish in Alaska, coordinating future studies, and deciding how and when to apply the results of those studies to current management practices.
- Conducting research to define the minimum conditions for imprinting for remote release programs.