Marine Resource Economics, Volume 8, pp. 249–271
0738-1360/93 $3.00 + .00
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Using an International Econometric Model to Forecast Alaska Salmon Revenues

Mark Herrmann

Assistant Professor
Department of Economics
University of Alaska Fairbanks

Abstract *As Alaska prices tumbled in the 1990s, Alaska's Senate Special Committee on Domestic and International Commercial Fisheries requested a comprehensive review of the Alaska salmon enhancement program. As part of this review, a revenue analysis was performed to examine the effects of various salmon enhancement production levels on future revenue generated to salmon fishers working in Alaska waters. The results were then used in a cost/benefit analysis of the state's enhancement program for sockeye, chinook, coho, chum, and pink salmon. This report focuses on the two most important Alaska salmon species, sockeye and pink. Results of the revenue analysis indicate that for sockeye salmon, future revenues would increase if output from salmon enhancement were expanded. For pink salmon, revenues would decrease if salmon enhancement were expanded and increase if salmon enhancement were scaled back. However, a complete elimination of the pink hatchery program would decrease revenues. For both species, there are important regional differences.*

Keywords Revenue, international, econometrics, Alaska, salmon, hatchery.

Introduction

In the early 1970s, Alaska production of salmon was declining and the state was unable to take full advantage of lucrative salmon prices. Alaska, which was once the dominant supplier of salmon worldwide, was losing its hold on salmon markets. In response, the state of Alaska developed an extensive salmon hatchery program designed to create a stream of revenue from this valuable renewable resource. Funding came, in part, from the state government's share of Alaska's North Slope oil. There was little concern at the time about a possible glut of salmon on world markets.

However, since 1988 Alaska salmon prices have steadily declined (see table 1). For Alaska's most prolific enhancement species, pink salmon, total exvessel value has decreased from $141 million to $44 million despite the doubling of landings. For sockeye salmon, the second largest enhanced salmon in terms of volume, exvessel value declined from $443 million to $199 million despite a 38

This paper is a result of research sponsored with funds from the Alaska State Senate Special Committee on Domestic and International Commercial Fisheries, Alaska Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, under grant no. NA90AA-D-SG066, project #R/14-13, and from the University of Alaska Faculty Small Grants Program.

Table 1
Alaska Salmon Harvest Volume, Harvest Value, and Exvessel Prices, 1980–1991

Alaska Harvest Volume (million pounds)

Fishery	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Average
Chinook	12.5	15.7	16.9	15.7	12.5	15.5	11.7	13.3	10.9	11.3	11.5	10.7	13.2
Sockeye	186.7	226.0	188.6	305.6	222.7	221.5	194.6	224.8	188.6	260.7	306.0	259.0	232.1
Coho	22.4	25.8	46.5	26.8	44.5	47.3	46.6	25.3	35.5	33.2	40	43.9	36.5
Pink	217.9	245.0	219.1	194.1	276.7	304.3	259.3	164.8	177.9	331.5	271.9	349.3	251.0
Chum	71.8	99.5	91.2	79.1	104.1	83.4	97.1	80.4	121.6	61.6	62.7	66.3	84.9
TOTAL	511.3	612.0	562.3	621.3	660.5	672.0	609.3	508.6	534.5	698.3	692.1	729.2	617.6

Alaska Harvest Value (million of dollars)

Fishery	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Average
Chinook	17.8	23.7	27.0	18.2	21.8	20.8	17.8	26.8	29.6	20.9	21.5	20.4	22.2
Sockeye	109.5	196.3	155.9	212.8	171.9	218.2	278.0	348.2	443.2	369.9	393.0	199.1	258.0
Coho	17.9	23.7	40.0	16.2	42.7	42.6	42.0	28.8	61.8	27.1	40.5	29.5	34.4
Pink	77.1	106.0	47.5	48.0	70.5	71.9	62.0	69.1	141.3	144.7	90.8	44.3	81.1
Chum	32.1	47.6	39.2	25.0	36.3	33.0	34.4	37.1	105.5	24.4	28.4	18.4	38.5
TOTAL	254.4	397.3	309.6	320.2	343.2	386.5	434.2	510.0	781.4	587.0	574.2	311.7	434.1

Alaska Exvessel Prices (dollars/pounds)

Fishery	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Average
Chinook	1.42	1.51	1.60	1.16	1.74	1.54	1.52	2.02	2.71	1.85	1.88	1.90	1.74
Sockeye	0.59	0.87	0.83	0.70	0.77	0.99	1.43	1.55	2.35	1.42	1.28	0.77	1.13
Coho	0.80	0.92	0.86	0.60	.96	0.90	0.90	1.14	1.74	0.82	1.01	0.67	0.94
Pink	0.35	0.43	0.22	0.25	0.25	0.24	0.24	0.42	0.79	0.44	0.33	0.13	0.34
Chum	0.45	0.48	0.43	0.32	0.35	0.40	0.35	0.46	0.87	0.40	0.45	0.28	0.44

Source: University of Alaska, *Alaska Salmon Markets*, May 1992.

percent increase in landings. The 1991 prices for all species are only a fraction of their 1988 values, from 70.1 percent for chinooks to 16.5 percent for pinks.

Much of this decline has been due to a rapidly increasing supply of captured and pen-raised salmon. The supply of world salmon has nearly doubled since 1980 (see table 2). While the supply of Alaska salmon has been growing, the majority of the increased supply comes from farmed salmon. Led by Norway, farmed salmon now accounts for nearly 30 percent of the world's total production. While Norway's production has declined somewhat, farmed salmon continues to grow from countries such as Chile. In addition, Russia is now increasing its exports to western markets. Harvests in Russia have recently been at record levels. In 1991, Russia had a pink harvest of 476 million pounds, exceeding the pink harvest of Alaska. Large supplies are expected to continue from the twenty-four salmon hatcheries in the Russian Far East (RFE), and with the help of Japan, Russia continues to seek hard currency through salmon trade (Greenberg *et al.* 1993). Remarkably, in 1992, Russia was the third largest exporter of salmon to Japan moving ahead of Canada (Knapp *et al.* 1993).

In part due to lower salmon prices, in May 1991 the Alaska State Legislature called for the first comprehensive evaluation of the state's salmon enhancement program. Part of the study was designed to address potential impacts of future changes in the state and private non-profit (PNP) salmon enhancement program to the economic returns from Alaska salmon fisheries. These impacts were analyzed through an econometric supply and demand equilibrium model of the world salmon market.

The economic portion, performed by researchers at the University of Alaska Fairbanks, included (1) a salmon population and exploitation model, (2) an international salmon market model, (3) a commercial salmon fishing cost model, (4) salmon enhancement costs, and (5) a salmon enhancement simulation model. This is one of three articles that examine the benefits of the Alaska salmon enhancement program to the state of Alaska (see also Boyce *et al.* 1993 and Boyce 1993).

Research Objectives

This salmon market analysis was commissioned to predict a fifteen-year stream of prices and revenues for Alaska salmon by species and area. The resulting prices and revenues were used on a cost/benefit analysis (see Boyce *et al.* 1993). The projections were made under a series of seven scenarios that examined effects of various future commercial catches of salmon due to various levels of enhanced fish. The scenarios are listed in table 3. Case 1 is a base line scenario in which production from future enhancement is based on current capacity constraints. Each subsequent scenario is based on an increase or a decrease in enhancement from current levels. Cases 2 and 3 examine the scenarios in which the pink and sockeye programs are discontinued entirely.

The regions examined included Cook Inlet, Kodiak, Prince William Sound, Southeast Alaska, Western Alaska, and the state's total (see figure 1). The first four contain essentially all of Alaska's enhanced salmon. All nonenhanced regions are combined into Western Alaska. The projected gross revenues for each case examined will be reported here. The five species of salmon caught in Alaska

Table 2
World Salmon Harvest Volume 1980–1991 (million pounds and percents)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Average
Alaska. Wild	511	612	562	621	661	672	609	509	535	698	692	729	618
Russia Wild	219	238	148	295	179	291	174	305	179	400	264	554	270
World Farmed	15	26	33	48	74	102	156	210	319	479	621	—	—
% Alaska Wild	41%	44%	43%	31%	44%	34%	41%	33%	30%	34%	29%	—	—
% Russia Wild	18%	17%	11%	18%	12%	15%	12%	22%	10%	19%	13%	—	—
% World Farmed	1%	2%	3%	3%	5%	5%	11%	14%	18%	22%	28%	—	—
TOTAL[1]	1242	1379	1307	1595	1512	1948	1458	1390	1726	2089	2056	—	

[a] Total includes all other countries' production not reported.

Source: Alaska Salmon Marketing Institute. *Salmon 2000.*, March 1991. Streletsky, Andrei. "Russian Far East and Alaska Fishery." Unpublished Paper, University of Alaska Fairbanks, December 1992. University of Alaska, *Alaska Salmon Markets*, May 1992.

Table 3
The Alternatives Considered in the Policy Analysis

Case	Scenario
1	Maintain current enhancement production
2	Eliminate entire pink salmon enhancement production
3	Eliminate entire sockeye salmon enhancement production
4	Increase pink salmon enhancement production level by 15%
5	Decrease pink salmon enhancement production level by 15%
6	Increase sockeye salmon enhancement production level by 15%
7	Decrease sockeye salmon enhancement production level by 15%

include sockeye (also called reds), chinook (also called kings), coho (also called silvers), chum (also called dogs), and pink (also called humpies) salmon.[1]

Research Methods

The model used to predict prices and revenues generated to fishers in Alaska was estimated into two interlinking models. The first model (bloc 1) is a forty-eight equation international supply and demand model that estimates the salmon flow relationships (shown in figure 2) by Bayesian Two-Stage Least-Squares analysis. The second model is a twenty-equation model that links regional Alaska salmon prices to a more aggregated definition of salmon prices from bloc 1 and was estimated using ordinary least squares. The estimated econometric models were combined in model simulations, which provided the vehicle for examining impacts of future changes in salmon hatchery production to statewide and regional salmon exvessel revenues and prices. Using projected levels of exogenous variables in dynamic simulation, prices and revenues for 1992–2006 were forecasted using the Newton Algorithm in SAS ETS (SAS 1988).[2]

Bloc 1: Formation and Estimation

The first bloc provides a model of historical international salmon wholesale price formation. The model encompasses the wholesale salmon markets of North America, Japan, Norway, the European Economic Community, Chile, Australia, and New Zealand. The second bloc models the historical relationship between North American wholesale prices and regional Alaska exvessel prices for the five salmon species harvested in Alaska.

As mentioned, one goal of this study was to project future Alaska salmon exvessel prices through the year 2006 under varying hatchery production levels. Alaska exvessel prices depend, in part, on wholesale prices, so an economic model must consist of a system of equations that models salmon price formation at both the wholesale and exvessel levels. This modeling framework is considered

[1] In the study for the state the effect of enhancement changes on all five species were examined. In this paper results on only two of the most important species, sockeye and pink salmon are presented.

[2] 1992 was the first year of forecasting because the model was estimated with data up to 1991.

Figure 1. Map of Alaska.

particularly critical for this study, where the modeling emphasis is placed on projecting long-term price movements, rather than simply forecasting exvessel prices one year into the future.

A model designed to project exvessel prices only one year into the future might include Alaska Department of Fish and Game forecasted run sizes, current U.S., Canadian, and Japanese wholesale prices and inventories, and other supply and demand determinants; however, these variables are not available beyond the current time period. Thus, these variables had to be generated internally within a model designed to project exvessel prices fifteen years into the future. The model must explicitly account for the interlinkages that exist between the various salmon markets at the wholesale level, as well as the interlinkages between the wholesale and exvessel levels. Model performance is evaluated on the basis of the model's ability to predict long-term average price movements, rather than to predict exvessel prices in any single year.

The size of the econometric model prevents a full presentation in this article (see Herrmann and Greenberg 1993 for a complete presentation of the estimated model). A summary of the behavioral equations found in bloc 1 are presented in table 4. The model includes flows of farmed salmon from Norway, Scotland, Chile, British Columbia, Ireland, and the United States. The farmed salmon from Norway, Ireland, and Scotland is exclusively Atlantic salmon, whereas the farmed salmon from the United States, British Columbia, and Chile is a mixture of Pacific and Atlantic salmon. North American salmon exports include all species of Pacific salmon, and Japanese landings of salmon include all species of Pacific salmon, although the majority of Japanese landings are chum. Even with these specifications, the model is sufficiently detailed to provide insight into price formation in the world salmon markets.

Wild Pacific salmon was divided into two product groups consisting of high-valued Pacific salmon (chinook, coho, and sockeye), and low-valued Pacific

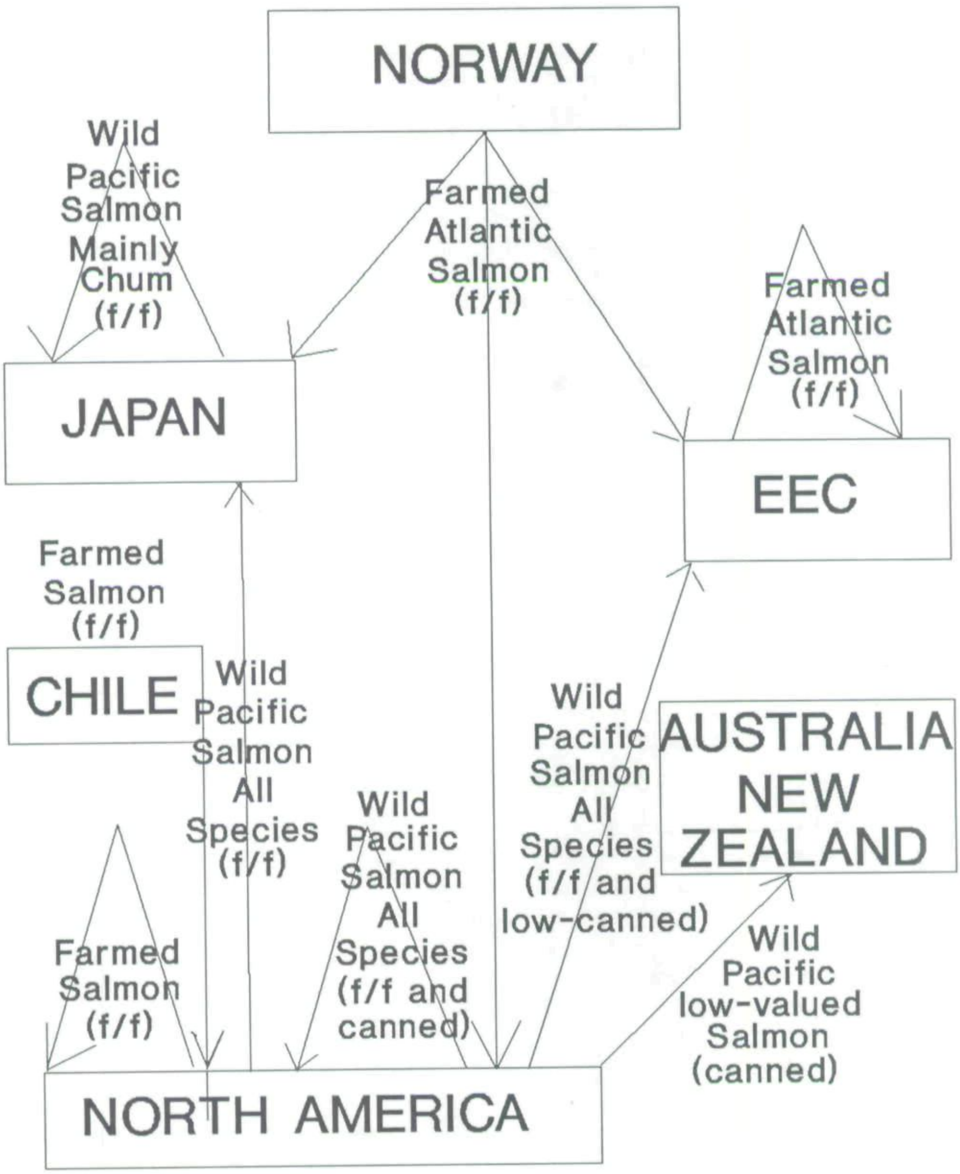

Figure 2. Flow Chart—Bloc 1.

salmon (chum and pink). These groupings were based on like exvessel value and were necessary to limit the number of equations in bloc 1 to a manageable size.

In addition to the two exvessel price equations, there are twenty-three behavioral equations and seventeen identities. The model was estimated over the period from 1982 (1981 was used for lagged endogenous variables) to 1991. Because the results of these estimations would be too lengthy to present in this paper, a summary of some of the more interesting findings is presented here:

North American Salmon Allocation. These equations were based on allocation theory where one export price is established and the spread between the prices for salmon received from the individual importing countries were due to seasonality

Table 4
Summary of Behavioral Equations in Bloc 1

North American Allocation of Wild Pacific Salmon
Quantity allocated of high-valued salmon to Japan[a]
Quantity allocated of high-valued salmon to the EC
Quantity allocated of low-valued salmon to Japan
Quantity allocated of low-valued salmon to the EC
Canned quantity of low-valued salmon allocated to the EC Australia, and New Zealand
Norwegian Allocation of Farm-Raised Atlantic Salmon
Quantity allocated to the EC
Quantity allocated to the Japan
Quantity allocated to the United States
North American Demand
Quantity demanded of Norwegian farmed Atlantic salmon
EC Demand for Salmon
Quantity demanded of Norwegian farmed Atlantic salmon
Quantity demanded of North American wild high-valued Pacific salmon
Quantity demanded of North American wild low-valued Pacific salmon
Quantity demanded of North American wild low-valued canned Pacific salmon (combined demand with Australia and New Zealand
Japanese Demand for Salmon
Quantity demanded of Norwegian farmed Atlantic salmon
Quantity demanded of North American wild high-valued Pacific salmon
Quantity demanded of North American wild low-valued Pacific salmon
Japanese Inventory Holdings
Japanese Inventory of Frozen Salmon
Japanese Inventory of Salted Salmon
North American Inventory Holdings
Quantity of wild high-valued salmon inventory
Quantity of wild low-valued salmon inventory
Quantity of canned wild low-valued salmon inventory
North American Exvessel Prices
Price of wild high-valued salmon
Price of wild low-valued salmon

[a] All quantities refer to fish/frozen quantities unless otherwise specified as canned.

factors, contractual arrangements (*i.e.* spot vs. forward contracting, bulk purchases, goodwill, *etc.*), and structural shocks. The equation for total North American high-valued salmon exports was modeled as a function of weighted average export price and beginning available supply. As the price received for the salmon increases more salmon is exported and less remains in the domestic market or is stored as inventory. The price received from the EC was theorized to differ from the price received from Japan depending on quarter and contractual differences. The allocation of low-valued fresh/frozen salmon was likewise modeled, with the price mapping equation working best when the Japanese price was the dependent variable. The allocation of low-valued canned salmon to an aggregate country made up of the EC, New Zealand, and Australia was found to be dependent on price received, and total available beginning supplies.

Norwegian Allocation of Farmed Atlantic Salmon to North America, Japan, and the EC. These equations were estimated as a function of prices received from the three regions, the total supply allocated to the three regions, a one-quarter lagged dependent variable, and seasonal indicator variables (the EC allocation was estimated by identity). The signs on the price coefficients indicate that Norway will allocate more salmon to the country in which it receives a higher price, subject to a partial adjustment process, suggesting that some short-term arbitraging is occurring. The import elasticities of supply (0.43 and 0.83 for exports to the United States in the short and long run, respectively) suggests that Norway is not increasing its exports to the United States proportionally to its increasing total exports. This is not surprising since the United States has placed sizable tariffs on imported Norwegian farm-raised Atlantic salmon. In fact, two indicator variables pick up downward shifts in exports to the United States beginning in the quarters that the tariffs took effect. In September 1990, the United States placed a temporary 12 percent tariff on imports of Norwegian farmed Atlantic salmon, and in March 1991 it increased this tariff to 16 to 32 percent tariff depending on producer. The negative coefficients on these two indicator variables suggest a large structural decrease in salmon exports to the United States due to the tariffs.

North American Demand for Norwegian Farmed Atlantic Salmon Imports. This equation was estimated as a function of own-price, a substitute price representing the North American weighted average export price of high-valued salmon, disposable personal income, quarterly indicator variables, imports of Chilean-raised farmed salmon, and a one-quarter lagged dependent variable. The mean-level own-price import elasticity of demand of −1.761 indicates that Norwegian farmed Atlantic salmon is price elastic in the United States. This elasticity is larger than that found in Herrmann 1990.[3] This may reflect that U.S. tariff-related increases in prices have led to lower U.S. consumption of Norwegian farmed Atlantic salmon. The income elasticity of 1.691 suggests that farmed Norwegian Atlantic salmon is income superior. The cross-price elasticity showed a 99.6 percent probability of high-valued North American salmon being a substitute for imported Norwegian Atlantic salmon, with a mean-level elasticity of 0.719.[4] The cross-quantity import elasticity of foreign-raised farmed salmon (a sum of Canadian and Chilean farmed exports to the United States) is negative at the 0.994 significance level. The negative coefficient of −0.259 means that a 1-pound increase in imports of farmed salmon from Chile or Canada displaces 0.259 pounds of imported salmon from Norway, everything else held equal. Quarterly indicator variables indicate a downward shift in the demand curve in the third quarter when the U.S. fishing season is at its peak.

[3] The model used previous studies (Herrmann (1990)) was a smaller model using 36 equations and was a precursory to this one. Nevertheless, many of the demand equations were similarly specified and some comparisons can be made to the differing sample period. The sample period in the prior model was 1982 to 1988 whereas the current sample period for this model is 1982 to 1991.

[4] The significance statistics reported can be literally interpreted as the probability that a parameter will be greater than zero for a coefficient estimated to be positive and that a parameter will be less than zero for a parameter estimated to be negative. (See Herrmann 1990 for further explanation on Bayesian Analysis).

EC Demand. The equations for EC demand were estimated as a function of own-price, substitute prices and/or quantities, private expenditures, quarterly indicator variables, lagged dependent variables, and other relevant indicator variables. In the Atlantic salmon equation, the import own-price elasticity indicated demand is slightly elastic at −1.283. The income elasticity is over 2.0. These elasticities are both below the ones found in Herrmann 1990, possibly reflecting increased supplies and lower prices of world salmon in recent years. High-valued Pacific salmon was found to be a substitute for Atlantic salmon with a probability of 61 percent. This probability of substitution is also lower than that found in Herrmann 1990, and may reflect increased dominance of Norwegian, Scottish, and Irish farm-raised salmon in the EC over U.S. exports of high-valued wild salmon (primarily chinook). Low-valued salmon was not found to be a substitute for Atlantic salmon. The own-price elasticity of North American high-valued salmon imports differs only slightly from −1.0. This is also well below the own-price elasticity found in Herrmann 1990. This provides one more indication that the effect of the rapidly increasing world supply of salmon has decreased demand for U.S. salmon. Atlantic salmon was found to be a significant substitute for North American high-valued salmon (probability of 97.6 percent). Additionally, low-valued Pacific salmon was found to be a substitute for high-valued salmon with a probability of 96.3 percent. The own-price elasticity for low-valued Pacific salmon imports into the EC exhibit an own-price elasticity close to −1.0. Surprisingly, this elasticity is almost identical to the own-price elasticity for high-valued salmon. This might be explained by the direct impact of increased Atlantic salmon consumption in the EC on the demand for high-valued Pacific salmon imports through direct competition but only indirectly affecting the demand for low-valued Pacific salmon. This may have shifted the demand for high-valued salmon inward sufficiently such that it is no more profitable (in terms of marginal revenue) than low-valued salmon as an export commodity to the EC. However, examining the income elasticity, it is clear that an increase in income will expand the demand for high-valued Pacific salmon imports far more than it will for low-valued Pacific salmon imports. The own-price elasticity for low-valued canned salmon imports is inelastic at −0.423, and the income elasticity is also below 1.0. High-valued canned Pacific salmon was found to be a substitute for low-valued canned salmon at a probability of 0.789.

Japanese Demand for Salmon. This was estimated as a function of its own price, substitute prices, private expenditure, inventories, quarterly indicator variables, and Japanese landings. In addition, the Japanese demand for Norwegian farmed Atlantic salmon has a four-quarter lagged quantity to capture a partial adjustment process. The coefficients for Norwegian farmed salmon in Japan show import own-price and income elasticities of −2.537 and 2.002, respectively. High-valued salmon was found to be a substitute with a 99.6 percent probability. Low-valued salmon was not found to be a substitute for the high-priced Atlantic salmon. The long-run elasticities are twice that of the short-run elasticities. The import own-price elasticity in the Japanese demand for North American high-valued salmon imports was slightly elastic at −1.252. The income elasticity was 3.574. The own-price elasticity was, again, far lower than the elasticity found in the 1990 study. Elasticities indicate that a 1-percent increase in the Japanese inventories of frozen salmon will decrease imports of North American high-valued salmon by 0.62 percent. Tuna was found to be a substitute good with high-valued salmon. The own-price import elasticity for low-valued salmon was −0.827. The income elasticity was 1.516, which indicates some demand sensitivity to the Japanese economy, although not as much as high-valued salmon or Atlantic salmon. A 1 percent increase in the total inventory of Japanese salmon displaces 0.639 percent of North American low-valued salmon imports.

Japanese Pacific Salmon Inventory. The Japanese inventory equations were estimated as a function of Japanese import price of salmon, the lagged import price, quarterly indicator variables, other indicator variables, beginning inventory levels, import quantities, and the Japanese discount rate, which was used to proxy the cost of storing salmon. A complete theory of how the above specifications were formed can be found in Herrmann 1990. The theory involved a partial adjustment process and both a speculative motive and a transactions motive where a buffer is formed to represent the risk of running short on salmon supplied. In sum, we would expect that, as the current import price increases, less inventory would be held and more released onto the market. As the lagged export price increases, we would expect, more salmon would be held in inventory as a speculative maneuver (see Herrmann 1990). The ending inventory levels are also a function of stocks on hand, an idea originating from the buffer theory of inventory motivation. Finally, the interest rate partially captures the cost of storing salmon, reflecting its negative coefficient.

North American Pacific Salmon Inventory. These equations were estimated as a function of North American weighted average export price of Pacific salmon, the total available supply of Pacific salmon, beginning inventories of Pacific salmon, quarterly indicator variables, and a one-quarter lag of the North American weighted average export price of Pacific salmon. Both equations indicate that North American inventories decrease when the current weighted average export price (used as a proxy for U.S. wholesale prices) increases, and these inventories increase when expectations of future wholesale price increase and beginning available supplies increase. Momentum (or friction), as defined in the partial adjustment theory, is incorporated into the equations through the beginning inventory variable. High-valued salmon was less responsive to prices and more responsive to the proportion held back from total supply than low-valued salmon. This indicates that processors have a more conservative attitude toward buffer stocks when dealing with the higher-priced product.

Exvessel Price Equations. The exvessel price equations are shown below for high- and low-valued North American Pacific salmon. The North American exvessel price equations were hypothesized to be a function of the appropriate wholesale prices, substitute prices, income, a constant, and quarterly indicator variables. The functional form used for the high-valued exvessel price equation was log-linear. For the low-valued exvessel price equation, the more standard linear form was utilized. One reason the linear and log-linear functional forms were chosen is that they allow the elasticities (or price flexibilities) to vary as landings vary. (The log-linear functional form was preferred for the high-valued exvessel price equation because it performed markedly better in simulation goodness-of-fit-statistics.) The equations are given below with the probability of the parameter being its calculated sign reported below. Variable definitions are shown in appendix A.

Equation (1): Price of High-Valued Pacific Salmon

$$\ln(\text{NAPHEX}) = -0.261 + \underset{(1.000)}{0.212^{*}\text{UPHX}} + \underset{(0.996)}{0.197^{*}\text{UPAU}} - \underset{(0.950)}{0.0014^{*}\text{UHSUP}}$$

$$- \underset{(1.000)}{0.722^{*}\text{DQ2}} - \underset{(0.896)}{0.301^{*}\text{DQ3}} - \underset{(1.000)}{0.850^{*}\text{DQ4}} - \underset{(0.999)}{0.476^{*}\text{D91}} + \underset{(0.890)}{0.000086^{*}\text{UY}}$$

Correlation coefficient = 0.957

Probability of prior range = 0.849

Probability of positive first-order autocorrelation = 0.451

Het Correction = Quarter 4

Sample period = 1982:1 to 1991:3

Equation (2): Price of Low-Valued Salmon

$$\text{NAPLEX} = \underset{(1.000)}{0.338^{*}\text{UPLX}} + \underset{(0.999)}{0.101^{*}\text{UPLXC}} - \underset{(0.875)}{0.000329^{*}\text{ULSUP}}$$

$$- \underset{(0.502)}{0.00207^{*}\text{DQ2}} + \underset{(0.982)}{0.188^{*}\text{DQ3}} + \underset{(1.000)}{0.278^{*}\text{DQ4}} - \underset{(0.997)}{0.102^{*}\text{D91}}$$

Correlation coefficient = 0.937

Probability of prior range = 0.874

Probability of positive first-order autocorrelation (ignorance) = 0.067

Het Correction = Quarter 3

Sample period = 1983:1 to 1991:3

The equation specifications were guided by the theory of derived demand. In both exvessel equations, the weighted average North American export prices (UPHX, UPLX, and UPLXC) were used in place of the wholesale price of fresh/frozen high- and low-valued Pacific salmon and canned low-valued Pacific salmon, respectively.[5]

The modeled equations were estimated in price-dependent form. This specification reflects that total available supply is essentially exogenous. North American landings are set by provincial and state governments, and it is assumed that these landings are not price-responsive once fishers have made the decision to fish

[5] This is necessary because quarterly wholesale prices for fresh/frozen salmon are not available. In addition, equations for the domestic demand for high- and low-valued salmon were not specified because the disappearance of fresh/frozen and canned salmon by quarter were unavailable and estimates of the representative quantities were deemed unreliable. However, some of the effect of the wholesale price should be picked up by both the weighted average export price and aggregate disposable North American income; both of these variables are highly correlated with wholesale price. Because of the absence of domestic demand equations for Pacific salmon, factors affecting wholesale demand are included in the reduced form equations.

actively. Positive inequality restrictions were placed on the weighted average export prices, substitution prices, and income; negative inequality restrictions were placed on the beginning available supplies.

In the high-valued exvessel price equation, farmed Norwegian Atlantic salmon was found to be a substitute for high-valued wild salmon, with a 99.6 percent probability, and income was found to be significant, with a 89 percent probability. Income was included, despite the lower probability, because of its potential importance in determining U.S. demand. The high-valued salmon exvessel price was positively correlated with the weighted average export price. In other words, as the export price increases or decreases, we would expect the exvessel price to move in the same direction. The quarterly indicator variables in the high-valued exvessel equation indicate a large positive increment in the first quarter exvessel price. Only a small amount of winter troll chinook is sold fresh domestically in this quarter, usually as a specialty item with a correspondingly high price.

In the low-valued exvessel equations, low-valued exvessel prices moved in the same direction as the weighted average export prices of both fresh/frozen and canned salmon. Income was not found to be significant. This should not be taken to indicate that income has no effect on domestic demand for canned salmon. Rather, income is probably a less significant determinant of demand for low-valued salmon than it is for high-valued salmon and, therefore, was not statistically discernible. For both equations an indicator variable marking 1991 was significant, indicating that the model could not fully capture the 1991 price decreases without the intercept shift.

The two exvessel equations are recursively linked to the salmon market model through their inclusion of the simulated weighted average export prices, which are derived from the simultaneously estimated twenty-eight behavioral equations of supply and demand. The resulting weighted average exvessel prices were then used in predicting Alaska exvessel prices by region.

Bloc 2 Estimates

The actual exvessel prices for high- and low-valued salmon (NAPHEX and NAPLEX, respectively) were utilized to derive the exvessel prices for the five salmon species harvested in the various regions. This derivation is based on the premise that there is a strong relationship between NAPHEX and the various regional sockeye, chinook, and coho exvessel prices, as well as NAPLEX and the various regional pink and chum exvessel prices. (The estimated exvessel prices for high- and low-valued salmon were used in the simulation in place of the actual values used in equation estimation.)

The regional exvessel prices were estimated in bloc 2 as a linear function of the appropriate North American exvessel price using ordinary least-squares (OLS) regression. The estimated exvessel price for a given region and species represents a weighted average value of the associated exvessel prices across gear types. Regional exvessel prices for sockeye, coho, chinook, pink, and chum were estimated for four regions: Prince William Sound (PWRP, PWSP, PWKP, PWPP, and PWCP, respectively), Kodiak (KKRP, KKSP, KKKP, KKPP, and KKCP, respectively), and Southeast (SERP, SESP, SEKP, SEPP, and SECP, and Cook Inlet (CIRP, CISP, CIKP, CIPP, CICP), respectively). In addition, an aggregate all-other exvessel price equation incorporating all other regions in Alaska was specified for each of the above species (AKORP, AKOSP, AKOKP, AKOPP, and AKOCP, respectively). All equations were estimated for the 1983–91 time period.

The estimation results for the sockeye, coho, and chinook salmon exvessel price equations are presented in table 5. The sockeye equations performed very

Table 5

Estimation and Historical Simulation Results for Prince William Sound, Cook Inlet, Kodiak, Southeast, and Rest-of-Alaska Sockeye Exvessel Prices, PWRP, CIRP, KKRP, SERP, and AKORP, respectively; Prince William Sound, Cook Inlet, Kodiak, Southeast, and Rest-of-Alaska Coho Exvessel Prices, PWSP, CISP, KKSP, SESP, and AKOSP, respectively; and Prince William Sound, Cook Inlet, Kodiak, Southeast, and Rest-of-Alaska Chinook Exvessel Prices, PWKP, CIKP, KKKP, SEKP, and AKOKP, respectively; for the 1983-1991 time period (t-values are presented parenthetically).

Exvessel Price	Constant	NAPHEX* Coefficient	R^2	DW
PWRP	−0.332	1.435	0.81	1.96
	(−0.93)	(5.76)		
CIRP	−0.099	1.096	0.90	2.01
	(−0.54)	(8.51)		
KKRP	−0.271	1.224	0.88	1.66
	(−1.22)	(7.94)		
SERP	−0.369	1.370	0.92	1.47
	(−1.75)	(9.34)		
AKORP	−0.234	0.995	0.90	1.83
	(−1.37)	(8.34)		
PWSP	−0.035	0.722	0.68	2.32
	(−0.14)	(4.08)		
CISP	0.025	0.511	0.79	1.80
	(0.19)	(5.46)		
KKSP	0.186	0.404	0.50	1.54
	(0.91)	(2.85)		
SESP	−0.190	1.079	0.77	1.99
	(−0.64)	(5.23)		
AKOSP	−0.025	0.578	0.79	0.74
	(0.64)	(5.52)		
PWKP	−0.040	1.375	0.85	2.07
	(−0.14)	(6.72)		
CIKP	0.678	0.386	0.68	1.76
	(5.08)	(4.14)		
KKKP	0.609	0.347	0.43	1.43
	(3.03)	(2.47)		
SEKP	1.147	0.944	0.54	1.88
	(2.61)	(3.07)		
AKOKP	0.641	0.614	0.47	0.70
	(1.95)	(2.68)		

* NAPHEX is a weighted average exvessel price for North American high-valued Salmon (sockeye, coho, and chinook).

well in estimating the Alaska regional and statewide sockeye exvessel prices for the 1983–91 time period with the R^2s for the sockeye exvessel price equations ranging from 0.81 (PWRP) to 0.92 (SERP). The R^2s for the coho exvessel price equations range from 0.50 (KKSP) to 0.79 (CISP and AKOSP). The R^2s on several of the chinook equations are relatively low. This is attributed, in part, to chinook salmon not being the targeted species in several fisheries. The R^2s range from a relatively low 0.43 (CIKP) to 0.85 (PWKP).

The estimation results for the pink and chum salmon exvessel price equations are presented in table 6. The pink estimates fit very well, with the R^2s ranging from 0.92 (CIPP and AKOPP) to 0.99 (PWPP, KKPP, and SEPP). The chum equations also fit well; the reported R^2s for the chum exvessel price equations range from 0.77 (PWCP) to 0.97 (SECP).

Forecasting

Forecasts of future salmon price levels are important for enhancement evaluation by policymakers and operators who want to make efficient resource allocation decisions. Three factors are critical in forecasting salmon prices accurately. First,

Table 6

Estimation Results for Prince William Sound, Cook Inlet, Kodiak, Southeast and Rest-of-Alaska, Pink Exvessel Prices, PWPP, CIPP, KKPP, SEPP, and AKOPP, respectively, and Prince William Sound, Cook Inlet, Kodiak, Southeast and Rest-of-Alaska Chum Exvessel Prices, PWCP, CICP, KKCP, SECP, and AKOCP, respectively, for the 1983–91 time period (t-values are presented parenthetically)

Exvessel Price	Constant	NAPLEX* Coefficient	R^2	DW
PWPP	−0.112	1.089	0.98	1.51
	(−4.77)	(20.55)		
CIPP	−0.055	0.838	0.91	1.48
	(−1.37)	(9.30)		
KKPP	−0.109	1.053	0.98	1.37
	(−5.49)	(23.57)		
SEPP	−0.095	1.075	0.98	2.24
	(−4.63)	(23.09)		
AKOPP	−0.029	0.867	0.91	1.76
	(−0.73)	(9.61)		
PWCP	−0.025	1.205	0.77	2.081
	(−0.24)	(5.22)		
CICP	0.137	0.773	0.79	2.67
	(2.18)	(5.44)		
KKCP	−0.112	1.341	0.91	2.86
	(1.70)	(9.00)		
SECP	0.025	1.246	0.97	2.071
	(0.72)	(16.09)		
AKOCP	0.149	0.530	0.80	1.81
	(3.58)	(5.63)		

the estimate model must be a reasonably accurate representation of equilibrium price and quantity formation within salmon markets; second, past market structure, upon which the salmon models are based, need to continue into the future; and third, the predetermined explanatory variables in the model must be accurately forecasted.

Forecasting prices for any commodity is difficult at best. Uncertainty as to the future conditions under which the modeled markets will operate and the future values of predetermined variables has always plagued forecasters. In addition, changing exchange rates also compound the uncertainty about future price levels. Salmon price forecasting is further complicated by the recent emergence of the farmed salmon industry. This is a relatively new market that is still in its developmental stages. It is not possible to fully model the impact of this market on salmon prices given its continuing evolution and brief history. Nevertheless, it is hoped that the forecasted prices will at least indicate magnitudes and directions of price movement.

Forecasting Exogenous Variables

Forecasting salmon prices over a fifteen-year time horizon requires specifying values for all exogenous variables for the forecast period of 1992–2006. Various methods were employed in specifying future exogenous variables, including econometric techniques involving time trends, holding the values of certain variables constant, and basing future values on researcher knowledge of the industry and expert opinion.

Exogenous variables that were forecasted using ordinary least-squares include populations and incomes for Japan and the EC. Variables that had future values maintained at beginning 1992 levels included exchange rates, consumer price indices, tariff rates, real interest rates, and the real price of the Japanese substitute fish prices. Each of the above variables was assigned the value observed in the first quarter of 1992. By assigning 1992 values to the future value of the CPI, the forecasted prices and revenues were in real 1992 dollars. Future values of exogenous variables for which expert opinion was used included U.S. real income (assuming a 3 percent real growth rate) and estimated future supplies of Norwegian, Scottish, Canadian, and Chilean farmed salmon.

All wild salmon harvests for Canada, Washington, Oregon, and California were estimated based on ten-year historical averages. All Alaska non-hatchery wild salmon harvests were estimated on the same basis, with the exception of Prince William Sound pinks, Cook Inlet sockeye, Kodiak sockeye and pink, and Southeast chinook salmon. Wild and hatchery harvests for these salmon species were predicted by a fisheries biologist at the University of Alaska Fairbanks located in Juneau (Collie 1993).[6] The ten-year average harvest was agreed upon by the Alaska State Senate and the Fisheries Research Enhancement Division (FRED). Future hatchery harvests for the other Alaska regions and species were estimated by the hatchery operators in a survey conducted by the state of Alaska.

[6] Collie's modeling effort used a standard approach to estimated catches of enhanced salmon as Hatchery Catch = Fry released * Survival * Exploitation Rate.

Simulated Case Scenarios

The estimated system of equations from bloc 1 and bloc 2 were combined in simulation to forecast future economic returns to the Alaska salmon industry. A variety of future case scenarios were simulated. These various scenarios assumed different future salmon hatchery production levels for the 1992–2006 time period. The base scenario, to which other scenarios were compared in deriving changes in exvessel revenues, assumes that salmon hatchery production will continue at levels consistent with current production practices.

Although the case scenarios involve altering state and PNP salmon hatchery production beginning in 1992, salmon harvests are not impacted until several years later, when the adult salmon return to Alaska fisheries. Therefore, revenue and exvessel price impacts for the various case scenarios were reported for the 1997–2006 time period. All revenues and prices were reported in constant 1992 dollars, referred to as real revenues and prices. (It should be noted that in no instance did a predicted salmon price fall below the price that would be needed to cover the cost of fishing and, therefore, the TAC was realized in each forecasted year.)

The predicted average harvests and real prices and revenues for 1997–2006 are within the historical bounds that have been observed in the past decade. The average sockeye salmon harvest is 246 million pounds, and the average exvessel price is $1.28 per pound (see table 7). The average predicted real revenue of $314 million is $57 million higher on average than the revenues from 1980 to 1991, although lower than those found from 1987 to 1991.

The predicted average annual pink harvest for Alaska is 326 million pounds. Predicted average real exvessel price and revenues are $0.30 per pound and 98 million pounds, respectively. Both the predicted average revenue and the harvest are slightly above those observed in the 1980s (the predicted price is 4 cents lower than the average 1980–91 price). The predicted price is also below actual 1987–90 prices but above the 1991 price.

The results presented in this section represent the 1997–2006 average annual real exvessel revenue changes from the base scenario that accompany a specified change in salmon hatchery production. Two sets of results are provided for each of the case scenarios: average real exvessel revenue changes are reported for each

Table 7

Case 1, Base Case Scenario Predicted Average Annual Harvests, Real Revenue, and Real Exvessel Prices for Alaska Sockeye, Pink, Chum, Coho, Chinook for 1997–2006

Fishery	Harvests (lbs.)	Price (lbs.)	Revenue (dollars)
Sockeye	246,094,406	1.279	314,820,833
Pink	326,720,701	0.301	98,300,914
Chum	147,756,451	0.436	64,726,666
Coho	43,054,879	1.029	44,312,483
Chinook	16,082,501	1.976	31,771,429
Total	779,708,938		555,932,325

Table 8

Case 2, Pink Salmon Program Eliminated, Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Pink, Cook Inlet Pink, Southeast Pink, Kodiak Pink, All All-Other-Regions Pink, Alaska Pink, Alaska Sockeye, Alaska Chum, Alaska Coho and Alaska Chinook, for 1997–2006

	Annual Revenue Changes (total 1992 dollars)
Prince William Sound Pink	−31,131,217
Cook Inlet Pink	−2,927,398
Southeast Pink	13,325,571
Kodiak Pink	1,988,567
Other Alaska Pink	4,324,181
Alaska Pink	−14,420,296
Alaska Sockeye	2,226,193
Alaska Chum	5,787,079
Alaska Coho	284,549
Alaska Chinook	112,114
TOTAL	−6,010,361

regional fishery harvesting the salmon species for which hatchery production is altered, and Alaska statewide exvessel revenue changes are reported across all salmon species.

Tables 8 through 11 provide the expected average annual exvessel revenue changes for case scenarios 2 through 3.[7] Tables 8 and 10 provide the simulation results for those case scenarios in which future hatchery pink salmon production is varied. Complete elimination of the pink hatchery program would result in Alaska statewide average annual exvessel revenues decreasing by $6.01 million (see table 8). However, a 15 percent reduction in pink salmon hatchery production would increase statewide average annual exvessel revenues by $2.93 million, whereas increasing pink hatchery production by 15 percent would result in statewide average annual exvessel revenues declining by $2.58 million (table 10).

The results indicate that, given current market conditions and structure, pink salmon may be overproduced. Reductions in pink salmon hatchery production would provide economic gains to the state fisheries. However, these revenue gains would occur only over some defined range of reductions in pink salmon hatchery production. A reduction in hatchery production beyond this range would

[7] The reported predicted prices and revenues are expected projections and are between forecasted upper and lower bounds. Only upper and lower bounds could be placed with certainty on the cross-price effects within salmon groupings "like species" in bloc 1 (e.g. chum vs. pink salmon). Cross-price effects between species in bloc 1 and own-price effects were estimated as point predictions. The substitution strength between like species is an area for future research. See Herrmann and Greenberg 1993 for a more detailed explanation.

Table 9

Case 3, Sockeye Salmon Enhancement Program Is Eliminated, Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Sockeye, Cook Inlet Sockeye, Southeast Sockeye, Kodiak Sockeye, All All-Other-Regions Sockeye, Alaska Sockeye, Alaska Pink, Alaska Chum, Alaska Coho and Alaska Chinook, for 1997–2006

	Annual Revenue Changes (total 1992 dollars)
Prince William Sound Sockeye	−12,655,458
Cook Inlet Sockeye	−3,536,406
Southeast Sockeye	−826,373
Kodiak Sockeye	−7,763,960
Other Alsaka Sockeye	12,978,386
Alaska Sockeye	−11,803,811
Alaska Pink	1,059,023
Alaska Chum	482,415
Alaska Coho	637,039
Alaska Chinook	251,165
Total	−9,374,169

reduce statewide salmon exvessel revenues. This is demonstrated by statewide exvessel revenues decreasing when the pink salmon enhancement program is eliminated.

The revenue impacts of changes in pink salmon hatchery production would not be equally distributed across Alaska regional pink fisheries. The two fisheries that would have their harvests significantly impacted by pink salmon hatchery production, Prince William Sound and Cook Inlet (which together produce 88 percent of Alaska's enhanced pink salmon), would experience increases in exvessel revenues if pink hatchery production were increased, and decreases if pink hatchery production were reduced. Exvessel revenues in the other pink fisheries, in which only a minor portion of harvest is comprised of pink salmon from the hatcheries, exhibit an inverse relationship with pink hatchery production due to the price effect being dominant—exvessel revenues would increase if pink hatchery production were reduced, or decrease if pink salmon hatchery production is increased.

The impacts of changes in sockeye hatchery production to exvessel revenues are provided in tables 9 and 11. Table 9 presents the revenue impacts of eliminating the sockeye enhancement program, and table 11 presents the impacts to fishery revenues if sockeye hatchery production were increased or decreased by 15 percent. In all cases, statewide exvessel revenues would decrease if sockeye hatchery production were decreased, and increase if sockeye hatchery production were increased. Elimination of the sockeye enhancement program would result in statewide average annual exvessel revenues decreasing by $9.37 million; and

Table 10

Cases 4 and 5, Production from Pink Enhancement Changes by 15 Percent, Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Pink, Cook Inlet Pink, Southeast Pink, Kodiak Pink, All All-Other-Regions Pink, Alaska Pink, Alaska Sockeye, Alaska Chum, Alaska Coho and Alaska Chinook, for 1997–2006

	Annual Revenue Changes (total 1992 dollars)	
	Increase Production	Decrease Production
Prince William Sound Pink	−2,181,894	1,509,859
Cook Inlet Pink	−244,389	166,102
Southeast Pink	2,115,462	−2,249,129
Kodiak Pink	493,543	−588,007
Other Alaska Pink	634,142	−651,804
Alaska Pink	816,865	−1,812,978
Alaska Sockeye	219,899	−208,925
Alaska Chum	874,643	−871,851
Alaska Coho	28,114	−26,705
Alaska Chinook	11,079	−10,522
Total	2,584,019	−2,930,981

reducing sockeye hatchery production by 15 percent would result in statewide average annual exvessel revenues decreasing by $1.29 million. A 15 percent increase in sockeye hatchery production would increase statewide average annual exvessel revenues by $1.29 million.

The principal beneficiary of an increase in sockeye hatchery production would be the Prince William Sound fishery. A 15 percent increase in hatchery production would lead to a $1.77 million increase in this fishery's average annual exvessel revenues. The largest losses from a 15 percent increase in sockeye hatchery production would be incurred by the aggregate Alaska Other-Regions sockeye fisheries (AKOR). These losses would accrue primarily to the Bristol Bay fishery, which is the dominant fishery within this aggregate group.

Conclusion

The salmon marketing model was constructed to predict a lengthy exvessel price stream under various enhancement scenarios. The accuracy of such long-term price predictions will depend on several important factors as discussed above. Thus, even though actual outcomes would likely vary from those predicted through the model, the model results will still be valid in terms of projecting the direction of future price movements.

The results of the model simulations indicate that Alaska's average annual exvessel revenues would increase over the 1997–2006 time period when sockeye

Table 11

Cases 6 and 7, Production from Sockeye Enhancement Changes by 15 Percent, Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Sockeye, Cook Inlet Sockeye, Southeast Sockeye, Kodiak Sockeye, All All-Other-Regions Sockeye, Alaska Sockeye, Alaska Pink, Alaska Chum, Alaska Coho and Alaska Chinook, for 1997–2006

	Annual Revenue Changes (total 1992 dollars)	
	Increase Production	Decrease Production
Prince William Sound Sockeye	1,767,067	−1,800,062
Cook Inlet Sockeye	545,179	−514,583
Southeast Sockeye	−114,284	18,768
Kodiak Sockeye	−988,757	1,050,612
Other Alaska Sockeye	−1,820,309	1,848,276
Alaska Sockeye	−1,594,978	1,633,928
Alaska Pink	−114,944	150,275
Alaska Chum	−67,970	68,504
Alaska Coho	−89,349	90,972
Alaska Chinook	−35,226	35,772
Total	−1,287,489	1,288,405

enhancement hatchery productions were increased. However, these increases would be moderate, and the actual profitability of increasing sockeye hatchery production of this species can only be determined when the revenue increases are compared to the costs of the programs. Cost considerations and determination of producer surpluses from the enhancement program are provided in a separate report.

The simulation results for future variations in the pink salmon enhancement program indicate that there may be an overproduction of pink salmon. Reducing pink salmon production by 15 percent would result in average annual exvessel revenue gains in both the statewide pink fisheries and the overall statewide salmon fisheries. However, there are distributional impacts which must be considered in conjunction with this result. For instance, the Prince William Sound pink fishery would suffer a significant reduction in exvessel revenue if pink hatchery production were reduced.

There are at least four points, which are not discussed above, that should be noted in evaluating the economic viability of various enhancement programs. Only the returns to the commercial fleet were considered in this analysis. Increased enhancement production of some salmon species, *e.g.* sockeye, would increase sportfishing harvests. Thus, the reported revenue increases provided in this report (which are confined to exvessel revenue) will understate actual benefits associated with increased salmon hatchery production. It may be useful in the future to consider incorporating economic impacts of the sport segment of the fishing industry into the economic analysis of the salmon enhancement program.

Second, variation in salmon hatchery production may affect prices and/or the recruitment/survivability of other fish species. Considerations of salmon enhancement impacts on other fisheries was beyond the scope of this analysis.

Third, it is clear from the model results that, across salmon species, increases in production/harvests will have only moderate impacts on salmon fishery exvessel revenues, at best. Current high levels of world salmon supplies severely hamper the ability of increased production to bolster economic returns to the salmon fisheries. It may be prudent to increase efforts aimed at expanding world demand for Pacific wild salmon. This would increase prices at all harvest levels and increase the ability of the world salmon market to absorb additional salmon production.

Finally, an increase or decrease in the production of any salmon species may trigger a countermove by competitors in the world salmon industry that may offset any potential gain from the production change. For example, a decrease in the Alaska pink salmon harvest could provide further incentive for the Japanese to invest in the potentially large Russian pink salmon industry. Thus, possible reactions of other participants in the world salmon industry must be considered when evaluating salmon enhancement policy.

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Appendix A: Definitions of Variables

NAPHEX = the exvessel price of North American high-valued salmon, in U.S. dollars per pound.
UPHX = the North American weighted average export price of high-valued salmon to Japan and the EC, in U.S. dollars.
UPAU = the nominal price of Norwegian farmed Atlantic salmon in the United States, in U.S. dollars.
UHSUP = the North American total available supply of high-valued salmon in millions of pounds.
D91 = an indicator variable which is assigned a value of 0 between 1983 and 1990, inclusive, and a value of 1 in 1991.
C = a constant.
NAPLEX = the exvessel price of North American low-valued salmon, in U.S. dollars per pound.
UPLX = the North American weighted average export price of low-valued salmon to Japan and the EC, in U.S. dollars.
UPLXC = the nominal export price of low-valued canned salmon exported to the EC, Australia and New Zealand.
ULSUP = the North American total available supply of low-valued salmon in millions of pounds.
UY = United States personal disposable income in millions of U.S. dollars.
DQ_is = quarterly indicator variables for quarter i, where DQ_i is 1 in quarter i and 0 elsewhere.
UPHX = the North American weighted average export price of high-valued salmon to Japan and the EC, in U.S. dollars.
PWKP, PWSP, PWRP, PWCP, and PWPP are the exvessel prices in the Prince William Sound fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
CIKP, CISP, CIRP, CICP, and CIPP are the exvessel prices in the Cook Inlet fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
KKKP, KKSP, KKRP, KKCP, and KKPP are the exvessel prices in the Kodiak fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
SEKP, SESP, SERP, SECP, and SEPP are the exvessel prices in the Southeast fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
PWK, PWS, PWR, PWC, and PWP designate the regions of the Prince William Sound fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
CIK, CIS, CIR, CIC, and CIP designate the regions of the Cook Inlet fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
KKK, KKS, KKR, KKC, and KKP designate the regions of the Kodiak fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.
AKK, AKS, AKR, AKC, and AKP designate the regions of the total Alaska fishery for chinook, coho, sockeye, chum, and pink salmon, respectively.

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