Chapter 4
Forecasts of Future Economic Net Returns

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4.0 Introduction

The chapter provides forecasts of how future average net economic returns in the Bristol Bay salmon drift gillnet fishery will vary depending upon the number of entry permits in the fishery and other assumptions about future conditions in the fishery.[1] The chapter also provides an estimate of the "economic optimum number" as described under Standard One in Alaska's limited entry law.

To review, Standard One under AS 16.43.290(1) is concerned with achieving a "reasonable average rate of economic return." It reads as follows:

> *(1) the number of entry permits sufficient to maintain an economically healthy fishery that will result in a reasonable average rate of economic return to the fishermen participating in that fishery, considering time fished and necessary investments in vessel and gear;*

"Economically healthy fishery" is further defined in AS 16.43.990(2) as follows:

> *(2)"economically healthy fishery" means a fishery that yields a sufficient rate of economic return to the fishermen participating in it to provide for, among other things, the following:*
>
> > *(A) maintenance of vessel and gear in satisfactory and safe operating condition; and*
> >
> > *(B) ability and opportunity to improve vessels, gear, and fishing techniques, including, when permissible, experimentation with new vessels, new gear, and new techniques.*

To make the forecasts, the authors developed an economic simulation model that is derived from relationships estimated from historic and survey data, and relies on assumptions about likely "future values" of key explanatory variables. As discussed later in this chapter, forecasts under a scenario that the authors believe is "most likely" suggest that the number of permits in the fishery would need to be reduced substantially to achieve positive economic profits per permit, on average, in the future.[2] Indeed, forecasts under a "high ex-vessel price" scenario also suggest that a substantial reduction from current levels would be needed.

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[1] In this report, the terms "economic returns," "net returns," and "net economic returns" will be used interchangeably. They all refer to a "net" residual that goes to the permit holder after some costs have been subtracted from gross earnings.

[2] Recall that economic profits, as defined herein, only occur after the opportunity cost of the investment in vessel and gear and the opportunity cost of the skipper's time have been covered.

Forecasting the future is fraught with uncertainties. Forecasting is not strictly a scientific exercise. All forecasts require many judgments on the part of the persons making the forecast. The factors that might influence the future are numerous and even if it were possible to enumerate all of the relevant factors it is unlikely that one could precisely foresee the exact influence of all of those factors on the future.

Nevertheless, reasonable forecasts are needed to help determine the optimum number of entry permits, particularly the number of permits that would be appropriate under the first optimum number standard which has been called the "economic optimum number."[3] For this reason, the authors have focused on some key variables that will definitely impact future economic returns in the Bristol Bay salmon drift gillnet fishery.

Chapter 3 provided estimates of historic average harvests, average gross earnings, average costs and average net economic returns per permit fished. The economic return measures used were "returns to labor, management, and investment" and "economic profits." The estimates show how average gross earnings and net economic returns have varied over time as run sizes, ex-vessel prices, and the number of permits fished have varied.

The historic net economic return estimates in Chapter 3 cover the time period from 1983 through 2003.[4] Average "returns to labor, management, and investment" per permit fished remained positive over the entire time period peaking in nominal dollars in 1990. However, the measure declined dramatically over the 1997 through 2003 time period.

Average "profits" per permit fished were positive over the 1983 through 1996 time period both in nominal dollars and real 2003 dollars. Average nominal profits per permit peaked in 1990, then tended to decline thereafter. Average profits per permit fished turned negative in 1997 in both nominal and real 2003 dollars, and remained negative thereafter with the exception of 1999.[5]

The declines in these net return estimates per permit fished and the negative estimates of average profits per permit fished since 1997 have occurred despite dramatic declines in the number of permits fished (see Table 3.2.a). This decline in the number of permits fished in recent years is a clear indication that the fishery has been unprofitable for many permit holders.[6]

While some of the decline in net returns is attributed to the drop in average pounds harvested over the 1997 through 2003 time period, a substantial decline in ex-vessel prices has also been a major factor. Sockeye ex-vessel prices in real 2003 dollars were lower over the 2000

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[3] See AS 16.43.290(1)

[4] See Table 3.2.a and Table 3.2.b. The 2002 survey did not try to collect data on fishing costs prior to 1983. Thus the time series for cost and net return estimates was confined to 1983 forward.

[5] Recall that the profits measure subtracts off a measure of the opportunity cost of the skipper's time and the opportunity cost of the investment in vessel and gear. The authors believe that the economic profit measure is the most appropriate measure to use under optimum number Standard One, because it explicitly takes into account "time fished and necessary investments in vessel and gear" as the standard in the law directs.

[6] Reducing the number of fishing operations will increase the average harvests, gross earnings, and net returns of the remaining permits being fished.

through 2003 time period than any sockeye ex-vessel prices experienced over the entire 1975 through 2003 time period.[7]

An important factor associated with the decline in ex-vessel salmon prices is the dramatic growth in the annual worldwide supply of farmed salmon and trout. Farmed salmon and trout are market substitutes for wild salmon; they compete either directly or indirectly with commercially harvested wild salmon. As the supply of farmed salmon and trout has increased, prices of farmed substitutes have declined substantially, impacting ex-vessel prices of all wild salmon species. The "high-valued" commercially harvested wild salmon, including chinook, coho, and sockeye salmon, have suffered substantial declines in real ex-vessel prices in recent years.

Some major factors that will determine future average net economic returns are the annual total harvest levels in the future and the ex-vessel prices in the future. Will total harvests continue to vary as in the recent past, or will harvests tend to be somewhat higher or lower in the future? Similarly, will ex-vessel prices vary as they have over the entire 1975-2003 time period, or will future ex-vessel prices tend to vary in a lower range, reflecting more recent market conditions? Will ex-vessel prices tend to decline further if the supply of farmed salmon and trout continues to grow? Alternatively, are real ex-vessel prices likely to rebound in the future?

To forecast future net economic returns, the authors built a simple simulation model for testing different assumptions about future scenarios. The following sections describe key components of the simulation model. Key assumptions for explanatory variables are outlined, and the results of three simulation scenarios are presented. As noted above, simulations under the baseline scenario, which the authors believe is "most likely", suggest that the number of permits in the fishery would need to be reduced substantially to achieve positive average profits per permit in the future.

4.1 Description of the Model and Key Assumptions

Many factors may impact future rates of economic return in the Bristol Bay salmon drift gillnet fishery. However, the ultimate variables that will determine average economic returns per permit are: the size of the future salmon harvests; the ex-vessel prices per pound that fishermen will receive in the future; the number of fishing operations in the fishery; and the costs associated with those fishing operations.

In the simulation model, the policy variable is the number of entry permits, which is the proxy for the number of fishing operations.[8] The goal of the model is to forecast what future average gross earnings, average harvests, average costs, and average economic profits will be

[7] See Table 3.1.b.

[8] Note that some regulatory schemes could result in permit consolidation, where there are fewer fishing operations than the number of permits. One method is mentioned in Chapter 2, where a new regulation in 2004 allowed two permit holders to consolidate on one vessel to fish a greater length of gillnet than what had been allowed in the past.

for varying numbers of permits, assuming that all permits are fished. The model can then show what permit levels are likely to be profitable, on average, in the future.[9]

The following subsections provide a brief overview of the assumptions used in the model and how the forecasts are made.

4.1.a Forecasts of Future Harvests

Other chapters in this report provide data on historic harvests and run sizes for the Bristol Bay salmon fishery as a whole, and for the Bristol Bay salmon drift gillnet fishery in particular. A key factor for forecasting future average economic returns is how run sizes and harvests will vary in the future. The size and composition of the harvest is important in determining the total gross earnings from the fishery. What will total harvests be for the Bristol Bay drift gillnet salmon fishery in the future?

To address this question, CFEC asked the Department of Fish and Game about how widely they expected sockeye run sizes and harvests to vary in the future. The focus was on sockeye salmon since it is by far the most important commercial species in Bristol Bay, and is the species most heavily studied. CFEC's questions to ADFG and the Department's responses are contained in two memoranda shown in the Appendices of this report.[10]

The Department's answers addressed their expectations about sockeye run sizes in the future. Based upon the answers, and the assumption that the allocation of harvests between the set and drift gillnet fisheries would remain relatively stable in the future, the authors assumed that sockeye harvests in the Bristol Bay salmon drift gillnet fishery would vary in the future as they have over the 1978 through 2003 time period. Sockeye harvests from 1975 through 1977 were not included because the harvest appeared to be too low in those years, given the minimum future run sizes suggested by the Department.[11]

The other salmon species are minor components of the total harvest in the Bristol Bay salmon drift gillnet fishery. The authors assumed that harvests of the other species would also vary as they had over the 1978 through 2003 period. Thus, with respect to the future, the model assumes that harvests for all Bristol Bay salmon will vary much in the same manner as harvests varied over the 1978-2003 period.

Sockeye run sizes and harvests for any particular year in Bristol Bay are likely to be related to run sizes and harvests in immediately preceding years. However, attempting to model that cyclical process was considered beyond the scope of the study. Instead, the authors decided to draw random samples from the 1978-2003 data to provide estimates of future harvests over the next 25 years.

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[9] Note that if the number of available permits is at a level that is not profitable on average, then operations which are not profitable will tend not to fish. The decline in the number of permits fished will make the fishery more profitable for the remaining participants.

[10] The questions are contained in an April 16, 2003 memorandum from CFEC to Kevin Duffy, the commissioner of the Alaska Department of Fish and Game. The answers to CFEC's questions are contained in a July 9, 2003 memorandum from Commissioner Duffy to CFEC (see Appendices).

[11] This assumes that the available surplus will be harvested. Economic conditions in the fishery could deteriorate to the point that portions of the available harvest would go unharvested. If so, the future harvest in some years could be lower than assumed herein.

To draw the samples, each year from 1978 through 2003 was given an equal probability of selection. Each random sample of 25 years was drawn "with replacement." Drawing samples with replacement means that harvests from any particular year could be drawn more than once within a 25 year sample. When the harvest data for a particular historic year were drawn for a particular future year, the harvest totals for each species in the historic year were used as the total harvest figures for each species in the future year.[12]

Bristol Bay sockeye ex-vessel prices are a function of harvest levels, and may also be time-related in the future if the growth of worldwide farmed salmon and trout production results in a continuing decline in the price of substitutes for Bristol Bay sockeye. Thus the sequence of years drawn in a random sample could impact the results.[13] To reduce the importance of any particular sequence of years resulting from a random draw, the authors chose to draw 100 random samples of twenty-five years each for simulations of each scenario.

The terms "samples" and "simulations" will be used interchangeably herein. To examine any particular scenario, the focus will be on the distribution of sample means from the 100 simulations of the scenario. Two underlying factors for harvests will vary in the simulations of a scenario: (1) the harvest drawn for any particular future year, and (2) the sequence of harvests drawn over the future 25 year period. Variations in the selected harvests leads to variations in ex-vessel prices, total pounds harvested, and total gross earnings. These, coupled with the number of permits, lead to variations in average pounds, average gross earnings, average costs, and average economic profits per permit in the model. In discussing results from the simulations of a scenario, the focus will be on the distribution of sample means from the 100 simulations.

In summary, the model assumes that harvests in the future will vary in a similar fashion as harvests that have occurred over the 1978 through 2003 time period.

4.1.b Forecasts of Future Sockeye Ex-vessel Prices

Future sockeye ex-vessel prices will be a key determinant for future total fishery gross earnings, average gross earnings per permit, and average profits per permit. Are future Bristol Bay sockeye ex-vessel prices likely to return to their historic higher levels, or do the recent declines in salmon ex-vessel prices foretell a future where prices will reflect the lower levels seen in more recent years? Will farmed salmon and trout production continue to grow and lead to even lower ex-vessel prices in the future?

Chapter 3 provided time series data on the Bristol Bay salmon drift gillnet fishery. The data include estimates of ex-vessel prices, total pounds harvested, total gross earnings, average pounds per permit, average gross earnings per permit, and economic profits per permit over

[12] Harvest totals by gear type were also used where needed.
[13] Ex-vessel prices may be time-related in the future, since farmed production of salmon and trout is continuing to grow. This growth has led to a decline in the price of substitutes for Bristol Bay sockeye and a "shift" in the demand curve for Bristol Bay sockeye inward. The falling price of farmed substitutes has reduced the demand for Bristol Bay sockeye and led to falling ex-vessel prices for Bristol Bay sockeye, for any harvest level. However, this report assumes that the price of farmed substitutes will not continue to trend downward.

sundry time periods since the limited entry program began. As noted above, the simulation model will assume that harvests in the future will vary in a similar manner as they did over the 1978 through 2003 time period. If ex-vessel prices varied in the same fashion as they did over the entire time period, then the fishery would likely remain, on average, profitable, even at the current level of between 1,800 and 1,900 permits in the fishery.

However, the growth in farmed salmon and trout production appears to have had a dramatic effect on ex-vessel prices for wild salmon, particularly since the late 1990's. Increased production of farmed salmon and trout and the decline of wild salmon ex-vessel prices have been discussed widely in academic papers, government publications, and press articles.[14]

To forecast future ex-vessel prices of Bristol Bay salmon, the commission sought the help of Dr. Gunnar Knapp, an economist at the University of Alaska Anchorage, Institute of Social and Economic Research (ISER). Dr. Knapp received his Ph.D in Economics from Yale University in 1981. He teaches courses at the University of Alaska Anchorage on natural resource economics and the economy of Alaska, and has conducted a wide variety of research on the Alaska economy and natural resource issues during his professional career. In particular, he has studied a wide range of fisheries issues.

Dr. Knapp is an expert on world salmon markets. Since 1990, Dr. Knapp has studied world salmon markets and the effects of changing market conditions on Alaska's salmon industry. From 1994 until 1998, Dr. Knapp directed the Salmon Market Information Service, which was funded by the Alaska Seafood Marketing Institute. Dr. Knapp has traveled to Japan, Russia, Norway, and Chile in connection with his research and has made numerous presentations to both academic and industry groups.

As part of his research, Dr. Knapp has closely followed and studied the growth of worldwide farmed salmon and trout production. In 2003, Dr. Knapp co-authored a study of world salmon markets for the Food and Agriculture Organization of the United Nations (FAO).[15] Dr. Knapp is currently working on an extensive report on the North American wild salmon industry with two other economists.[16] Dr. Knapp collects and maintains a data base on worldwide salmon markets in general, and Japanese markets in particular.

In 2003, the commission asked Dr. Knapp to help develop a forecasting methodology for future ex-vessel prices for all species of Bristol Bay salmon. Since the Bristol Bay fishery is predominantly a fishery for sockeye salmon, the primary focus of Dr. Knapp's work was to develop a forecasting methodology for future Bristol Bay sockeye ex-vessel prices. Dr. Knapp was asked to recommend a methodology which would be practical for use in this study, and would take into account important factors likely to affect future ex-vessel prices, including - but not necessarily limited to – future Bristol Bay sockeye harvests, monetary

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[14] For a recent example, see: *The Global Salmon Industry and It's Impacts in Alaska* by Neil Gilbertsen, published in Alaska Economic Trends; vol. 23, no. 10. Juneau: Alaska Department of Labor. October 2003.
[15] Trond Bjørndal, Gunnar Knapp, and Audun Lem, *Salmon - A Study of Global Supply and Demand*. FAO/GLOBEFISH Research Programme, Vol.73. Rome, FAO2003. 151 pages.
[16] G. Knapp, C. Roheim, and J.L. Anderson. *North American Wild Salmon: Economic Interactions with Farmed Salmon* (forthcoming 2004).

exchange rates, and the growth in the supply of farmed salmon and trout, which compete directly and indirectly with sockeye salmon in the marketplace.[17]

Dr. Knapp was also asked to prepare a detailed description of the major markets for Bristol Bay sockeye salmon and to develop some rudimentary forecasts of future Bristol Bay ex-vessel prices for the other salmon species. Dr. Knapp agreed to provide forecasts for key factors that might serve as explanatory variables in a projection model of salmon ex-vessel prices.

The resources available for Dr. Knapp's study were insufficient to attempt a detailed empirical analysis to explain the intricacies and the complex interactions of markets for Bristol Bay sockeye and for the market substitutes of Bristol Bay sockeye. Even if a detailed simultaneous equation econometric model were developed that adequately "explained" the variations in many wholesale and ex-vessel prices over a recent time period, it is likely that such a model would prove to be awkward and unwieldy to use for forecasting into the future.

To use an econometric model to forecast the values of a dependent variable(s) out into the future, one must first forecast the values of the "independent" or "explanatory" variables in the model out into the future. The greater the complexity of the model, the greater the number of explanatory variables that would need to be forecasted before one can make a forecast of the dependent variables, which are the main variables of interest.

Because of this, the authors and Dr. Knapp felt that a more detailed and complex model would not necessarily improve the accuracy of any forecast out into the future. Indeed, a complex model might increase the number of sources for possible error, since forecasts of more exogenous explanatory variables would likely be needed. Instead, the goal was to develop a simple forecasting equation for Bristol Bay sockeye ex-vessel prices. Ideally, the equation would do a reasonable job of explaining historic sockeye ex-vessel price variations using a small number of key explanatory variables, one of which would include the volume of Bristol Bay sockeye harvested in the year.[18]

According to Dr. Knapp's research, most Bristol Bay sockeye go into markets for frozen salmon in Japan or for canned salmon in Europe. Dr. Knapp's work indicated that the wholesale price of frozen sockeye in Japan did a reasonable job of predicting the ex-vessel price of Bristol Bay sockeye.[19] Since a large portion of the market for Bristol Bay sockeye is the frozen market in Japan, the Japanese market had to be a factor in any forecasting equation.

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[17] The results of Dr. Knapp's research for CFEC can be found in his forthcoming report titled: *Projections of Future Bristol Bay Salmon Prices*. An electronic copy of the report will be provided on the commission's website at www.cfec.state.ak.us.

[18] The reader should note that working with ex-vessel prices usually confines one to using annual data with fewer observations and degrees of freedom to estimate relationships. Relevant wholesale prices and quantities are sometimes available monthly, but the ex-vessel prices for a fishery like Bristol Bay are related to a harvest that occurs during a relatively short period of time in a year. More elaborate econometric models would likely utilize monthly data on wholesale prices, inventories, and trade flows to estimate demand and supply relationships among wholesale markets. They would then predict the annual ex-vessel price for a species as a simple function of the wholesale price. The monthly data provide more observations to try to estimate more complex relationships at the wholesale level. However, in this exercise, the goal was to develop a simple forecasting equation(s) that estimated the ex-vessel price directly, and did not require assumptions about future trends for large numbers of exogenous variables.

[19] The wholesale price explanatory variable was converted to dollar per pound units using the dollar per yen exchange rate. This methodology was used by Dr. Knapp herein on the Japanese wholesale price for farmed frozen coho explanatory variable.

Several different econometric specifications were estimated to try to predict historic Bristol Bay sockeye salmon ex-vessel prices in real 2003 (constant-value) dollars.[20] The equations attempt to predict the average annual Bristol Bay sockeye ex-vessel prices that have occurred over time.[21] The dependent variable was usually the Bristol Bay sockeye ex-vessel price measured in real 2003 dollars or the natural logarithm of that price.

All of the equations examined used some measure of the Bristol Bay sockeye harvest (in pounds, metric tons, or the natural logarithm of one of these measures) as an explanatory variable, since historically larger harvests have resulted in lower ex-vessel sockeye prices, and smaller harvests have resulted in higher ex-vessel sockeye prices, as economic theory would suggest. The sockeye harvest explanatory variable was usually significant and had an appropriate negative sign in all cases. This result would be consistent with an inelastic supply curve shifting along a downward sloping demand curve.[22] A relatively high Bristol Bay sockeye harvest would, *ceteris paribus*, lead to a lower ex-vessel price, and vice versa.[23]

Also examined as possible explanatory variables were the yen to dollar exchange rate and different surrogate measures for the price of close substitutes for Bristol Bay sockeye. In most of the estimated equations, these variables also proved to be highly significant and the estimated parameters had the expected signs. In some cases, worldwide farmed salmon and trout production or the imports of farmed coho into Japan were used as the surrogate for the price of the substitute product, under the logic that prices of farmed salmon and trout have fallen steadily as farmed supply has increased. The estimated parameters for these variables were also significant when included in the regressions.

After considerable study, the sockeye ex-vessel equation that Dr. Knapp recommended for forecasting purposes was relatively simple.[24] The dependent variable was the natural logarithm of the Bristol Bay sockeye ex-vessel price expressed in real 2003 dollars per pound. One explanatory variable was the natural logarithm of the Bristol Bay sockeye total commercial harvest, expressed in metric tons. A second explanatory variable was the natural logarithm of the simple annual average of the monthly Japanese wholesale price for frozen head-off farmed coho, expressed in real 2003 dollars per pound. This second explanatory variable represented the price of an important market substitute for Bristol Bay frozen

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[20] Under certain assumptions, a case could be made that the estimated equations are demand curves. However, the estimated equations do not necessarily represent demand curves and may represent hybrid curves that track the intersection points caused by both shifting demand and supply curves

[21] While the ultimate goal of the equation was to predict or forecast the sockeye ex-vessel price in real 2003 dollars, most equations used the natural logarithm of this price as the dependent variable.

[22] However, as stated previously, the demand curve has likely been shifting "inward" as the price of substitutes for Bristol Bay sockeye have fallen. Thus, for any level of Bristol Bay harvests, the resulting ex-vessel price for sockeye tends to be lower as the prices of substitutes for sockeye fall.

[23] *Ceteris paribus* means that all other factors that could impact the dependant variable are held constant.

[24] The key underlying equation used to predict the sockeye ex-vessel price is as follows:

LN_R03_BB_S420_XVP = 4.215984836 - (.530561022 LN_BB_S420_MT)
+ (1.397895537 LN_JAWHPRI_FARMCOHO_ANNREL03)

R-SQ = .830; adjusted R_SQ = .796; n = 13, degrees of freedom = 10.

Where:

LN_R03_BB_S420_XVP = the natural logarithm of the Bristol Bay sockeye ex-vessel price measured in 2003 dollars per pound.

LN_BB_S420_MT = the natural logarithm of the total Bristol Bay commercial sockeye harvest measured in metric tons.

LN_JAWHPRI_FARMCOHO_ANNREAL03 = the natural logarithm of the simple annual average Japanese monthly wholesale price for frozen "heads-off" farmed coho measured in real 2003 dollars per pound.

sockeye salmon and indirectly serves as a surrogate for the price of all substitutes for Bristol Bay sockeye.

Both explanatory variables were significant and had the expected signs. As Bristol Bay harvests increase in size, *ceteris paribus,* the ex-vessel price falls. As the prices of substitutes for Bristol Bay sockeye fall (based on the surrogate measure represented by the natural logarithm of the Japanese wholesale price for frozen farmed coho), *ceteris paribus,* the Bristol Bay sockeye ex-vessel price falls, and vice versa.

Some of the reasons Dr. Knapp decided to recommend this equation over others that were estimated can be found in his report to the commission. One of the key reasons is that he felt he could make a more reasonable forecast of the Japanese wholesale price for farmed coho salmon out into the future by using available data on trends in farmed salmon costs. He felt that this wholesale price explanatory variable could be more accurately forecast in the future than could other potential explanatory variables, such as the worldwide production of farmed salmon and trout.

After reviewing available articles and reports on the topic of farmed salmon costs, Dr. Knapp concluded that this Japanese wholesale price has already fallen to levels that roughly reflect the long run average cost of producing the farmed salmon and getting the fish to market.[25] Thus he does not expect this wholesale price to fall much further or rise much higher in the future over the long run, although there could still be substantial short-term fluctuations from year-to-year. He felt that this Japanese wholesale price for farmed coho salmon could be modeled as a long-term mean with annual random variation around that mean in the future.

The mean price that Dr. Knapp forecasts for the Japanese wholesale price of farmed coho explanatory variable in future years is $1.63 per pound, measured in real 2003 dollars. Dr. Knapp also suggests that variations in the price could occur on an annual basis, and he thinks that the variable could reasonably be modeled as a normally distributed random variable with a mean of $1.63 per pound and a standard deviation of $.20 per pound. The CFEC model has incorporated Dr. Knapp's suggestion for this important explanatory variable in the simulation model.

The sockeye ex-vessel forecasting equation recommended by Dr. Knapp does not incorporate a separate explanatory variable for the yen to dollar exchange rate. Historically, the exchange rate has clearly been important to sockeye ex-vessel prices, and the variable was highly significant in some other potential models of the sockeye ex-vessel price that were tried. Historically, a stronger dollar (relatively high yen per dollar ratio) has meant lower sockeye ex-vessel prices, whereas a weaker dollar (relatively low yen per dollar ratio) has meant higher sockeye ex-vessel prices.[26]

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[25] Farmed salmon has gone through a period of falling production costs. Dr. Knapp provides several reasons why these farmed salmon costs could continue to fall or start to rise in the future. Ultimately, he feels these factors will tend to balance out, and long-run average costs will remain relatively stable in the future, instead of continuing to trend downward. However, he points out that future costs of production for farmed salmon remain one important area of inherent uncertainty which will impact any effort to project the future of salmon markets and prices.

[26] Again, the result holds if all other factors are held constant.

However, Dr. Knapp notes he has implicitly incorporated the exchange rate into his sockeye ex-vessel price equation by converting the Japanese wholesale price for farmed coho from yen per kilogram (yen/kg) units to dollar per pound ($/lb) units using the exchange rate. Thus the Japanese wholesale price explanatory variable indirectly incorporates the exchange rate since it was converted from yen/kg to a $/lb measure.[27] The single variable in $/lb units also makes it easier for Dr. Knapp to compare the wholesale price directly with his estimate of the costs associated with producing farmed coho and getting it to the Japanese market.

Dr. Knapp also argues that over the long run, Japanese farmed salmon wholesale prices, measured in $/lb terms, will tend to become less dependent on potential future changes in the exchange rates. He notes that a future change in the yen per dollar exchange rate could impact the short-term wholesale price in Japan, as expressed in dollars per pound, for both Bristol Bay sockeye salmon as well as for competing farmed salmon and trout. However, over the longer term the price effects of an increase or decrease in the value of the yen would tend to be canceled out by increases or decreases in the supply of farmed salmon to the Japanese market.

A second, more practical consideration in omitting the exchange rate as an explanatory variable in the projection model is there has not been any notable trend in the nominal yen per dollar exchange rate over the past decade. Given the inherent uncertainty associated with how exchange rates may change in the future, Dr. Knapp indicated that if a forecast of the future exchange rate was needed as an explanatory variable, he would likely pick something close to the current exchange rate with some random variation around that number.

In summary, the sockeye ex-vessel price equation used in the simulation model is a model with two explanatory variables recommended by Dr. Knapp. The procedure for forecasting the Japanese wholesale price explanatory variable is also the one recommended by Dr. Knapp.

4.1.c Forecasts of Ex-Vessel Prices for the Other Bristol Bay Salmon Species

Forecasts of future ex-vessel prices were also needed for the Bristol Bay salmon species other than sockeye. The Bristol Bay fishery is predominantly a sockeye salmon fishery. Over the 1975 through 2003 time period, sockeye salmon accounted for approximately 91.3% of the pounds harvested and 95.5% of the ex-vessel gross earnings in the commercial fishery by both gear types. However, harvests of the other salmon species occur in Bristol Bay and contribute to the gross earnings and net economic returns of permit holders.

Since the total harvests of other salmon species are small relative to the total harvests of sockeye salmon, the results of the study were not going to be as sensitive to ex-vessel price forecasts for the other salmon species as they were to sockeye prices. For forecasting

[27] This procedure saved a degree of freedom which is important with the small number of observations available. An alternative treatment would have been to use the yen/kg wholesale price as one explanatory variable and the yen per dollar exchange rate (real or nominal) as a second explanatory variable. The alternative treatment would have cost one more degree of freedom and would have required projections of future trends in the exchange rate.

purposes in this study, Dr. Knapp suggested that a mean price calculated from a few recent years for each of the other salmon species might be adequate. Standard deviations of the prices for the same period could also be used. Then forecasts for the future could be made simply by making random draws from assumed normal distributions for each of the respective species.

The authors decided to estimate ex-vessel price forecasting equations from historic data in a fashion similar to what was done for the ex-vessel price of Bristol Bay sockeye salmon.[28] The spirit of the approach was to take advantage of the positive association between the sockeye ex-vessel price and the ex-vessel prices for other species.

The ex-vessel prices for all Bristol Bay salmon species appear to have been directly and indirectly impacted by the dramatic growth of farmed salmon and trout production. The falling prices for farmed salmon appear to have contributed to an "inward shifting" demand curve for wild salmon species, particularly the "high-value" species. Indeed, the Bristol Bay ex-vessel prices for chinook salmon, coho salmon, and sockeye salmon have followed a somewhat similar trend in recent years.

Table 4.1 provides time series data on CFEC's ex-vessel price estimates in both nominal dollars and real 2003 "constant value" dollars, for all of the Bristol Bay salmon species. The table indicates that the average ex-vessel price for Bristol Bay sockeye salmon has exceeded the average ex-vessel prices for Bristol Bay chinook and coho salmon in almost every year since 1986.

The authors tried several empirical specifications for each of the ex-vessel prices and also different time periods for making the estimates. The results for each specification varied somewhat depending upon the time period. The authors decided to use equations estimated over the 1983-2003 time period since this was the same time period over which the average cost equation was estimated. The equations used to forecast ex-vessel prices for each of the other salmon species are described briefly below.

[28] Dr. Knapp reviewed the approach the authors took to estimate ex-vessel price forecasting equations for the other salmon species. He also reviewed the actual equations that are used in the simulation model. He indicated that both the approach and the estimated equations were a very reasonable way to make Bristol Bay ex-vessel price forecasts for the other salmon species.

Table 4.1. Estimated Average Ex-vessel Prices for Bristol Bay Salmon, Prices are in Nominal and Real 2003 Dollars per Pound

	Sockeye		Chum		Coho		Chinook		Pink	
Year	Nominal Price	Real Price	Nominal Price	Real Price	Nominal Price	Real Price	Nominal Price	Real Price	Nominal Price	Real Price
1975	0.40	1.14	0.30	0.85	0.38	1.09	0.40	1.14	0.28	0.80
1976	0.50	1.32	0.32	0.85	0.42	1.11	0.49	1.30	0.31	0.82
1977	0.60	1.49	0.40	0.99	0.60	1.48	0.75	1.86	0.36	0.89
1978	0.73	1.69	0.40	0.93	0.77	1.79	0.72	1.67	0.33	0.76
1979	1.01	2.12	0.51	1.06	0.98	2.06	1.02	2.14	0.36	0.75
1980	0.57	1.08	0.34	0.65	0.56	1.06	1.01	1.92	0.25	0.48
1981	0.77	1.35	0.41	0.71	0.70	1.23	1.21	2.12	0.30	0.52
1982	0.69	1.14	0.35	0.59	0.75	1.25	1.22	2.04	0.22	0.37
1983	0.64	1.05	0.32	0.52	0.45	0.74	0.70	1.15	0.20	0.32
1984	0.66	1.04	0.30	0.48	0.76	1.20	1.03	1.63	0.23	0.36
1985	0.83	1.28	0.32	0.49	0.73	1.12	0.96	1.48	0.22	0.33
1986	1.42	2.15	0.31	0.47	0.68	1.02	1.00	1.51	0.15	0.22
1987	1.40	2.10	0.30	0.45	0.84	1.26	1.17	1.76	0.40	0.59
1988	2.10	3.15	0.47	0.70	1.38	2.06	1.11	1.66	0.35	0.53
1989	1.25	1.82	0.26	0.37	0.72	1.05	0.84	1.22	0.22	0.31
1990	1.09	1.50	0.27	0.37	0.78	1.06	0.93	1.28	0.32	0.44
1991	0.75	0.99	0.23	0.29	0.57	0.75	0.68	0.90	0.16	0.21
1992	1.12	1.42	0.27	0.34	0.60	0.76	0.94	1.19	0.14	0.18
1993	0.68	0.83	0.22	0.27	0.51	0.63	0.76	0.94	0.13	0.16
1994	0.99	1.20	0.22	0.26	0.66	0.80	0.64	0.77	0.12	0.15
1995	0.80	0.93	0.20	0.24	0.42	0.49	0.66	0.77	0.14	0.16
1996	0.81	0.92	0.11	0.12	0.31	0.35	0.51	0.58	0.05	0.06
1997	0.94	1.05	0.10	0.11	0.49	0.55	0.51	0.57	0.07	0.07
1998	1.21	1.34	0.09	0.10	0.44	0.48	0.62	0.69	0.08	0.09
1999	0.84	0.92	0.10	0.11	0.35	0.38	0.53	0.58	0.09	0.10
2000	0.67	0.72	0.09	0.09	0.35	0.37	0.46	0.49	0.08	0.08
2001	0.42	0.44	0.11	0.12	0.32	0.34	0.31	0.32	0.09	0.09
2002	0.49	0.50	0.09	0.09	0.31	0.32	0.33	0.34	0.06	0.06
2003	0.50	0.50	0.09	0.09	0.29	0.29	0.29	0.29	0.03	0.03

Note: Real prices were calculated using the Anchorage consumer price index.

Chum Salmon

Chum salmon are the second most plentiful species of salmon harvested in the Bristol Bay commercial salmon fisheries. Over the 1975-2003 time period, chums represented about 4.9% of the pounds and 1.7% of the gross earnings obtained from the Bristol Bay salmon fisheries.

The chum salmon ex-vessel price equation used the natural logarithm of the Bristol Bay chum ex-vessel price measured in real 2003 "constant-value" dollars as the dependent variable.[29] Two explanatory variables were used in the equation.[30]

The first explanatory variable was the natural logarithm of sockeye ex-vessel price measured in real 2003 constant-value dollars. The estimated coefficient was positive as anticipated and highly significant. The coefficient suggests that, *ceteris paribus*, chum prices will be positively associated with sockeye prices.

The second explanatory variable was the natural logarithm of the statewide chum harvest total measured in pounds. The coefficient on this variable was negative as anticipated and highly significant. The coefficient suggests that, c*eteris paribus*, higher statewide chum harvests lead to lower chum ex-vessel prices, while lower chum harvests lead to higher chum ex-vessel prices.

For forecasting purposes in the model, the statewide chum harvest explanatory variable comes from a random draw of historic data in the same fashion as the forecasts of Bristol Bay salmon harvests.

Pink Salmon

Pink salmon are a very minor component of the Bristol Bay salmon catch. Over the 1975-2003 time period, pinks represented only 1.4% of the total pounds and 0.4% of the ex-vessel gross earnings obtained from the Bristol Bay salmon fisheries

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[29] Again, the Anchorage consumer price index was used to convert nominal prices into real 2003 dollars. The results might have been slightly different if some other price index had been used to correct for general price inflation.

[30] The estimated equation for the chum ex-vessel price measured in real 2003 dollars is as follows:

$$\underset{}{LN\_R03\_BB\_D450\_XVP} = \underset{(3.66)}{16.10036} + (\underset{(4.20)}{.74871}\ LN\_R03\_BB\_S420\_XVP) - (\underset{(-4.01)}{.95153}\ LN\_SW\_D450\_LBS)$$

R-Sq = .7605; adjusted R-sq = .7338; number of observations = 21; degrees of freedom =18; Durbin-Watson statistic = .983 (serial correlation). The numbers in parentheses are T-values for the estimated coefficients.

Where:

LN_R03_BB_D450_XVP	=	The natural logarithm of the Bristol Bay chum salmon ex-vessel price measured in real 2003 dollars.
LN_R03_BB_S420_XVP	=	The natural logarithm of the Bristol Bay sockeye salmon ex-vessel price measured in real 2003 dollars.
LN_SW_D450_LBS	=	The natural logarithm of the statewide harvest of chum salmon measured in pounds.

Note the Durbin-Watson statistic indicates positive serial correlation of the residuals. For forecasting purposes, the authors decided to use the ordinary least squares estimated equation.

The pink salmon ex-vessel price equation used the natural logarithm of the pink ex-vessel price measured in real 2003 constant-value dollars as the dependent variable. Two explanatory variables are used in the equation.[31]

The first explanatory variable was the natural logarithm of sockeye ex-vessel price measured in real 2003 constant-value dollars. The estimated coefficient was positive as anticipated and significant. The coefficient suggests that, *ceteris paribus*, pink salmon prices will be positively associated with sockeye salmon prices.

The second explanatory variable was the natural logarithm of the statewide harvest total of "lower-valued" salmon measured in pounds. "Lower-valued" salmon were defined to include both pinks and chums. The coefficient on this variable was negative as anticipated and significant. The coefficient suggests that, c*eteris paribus*, higher statewide harvests of lower-valued salmon lead to lower pink ex-vessel prices and lower statewide harvests of lower-valued salmon lead to higher pink ex-vessel prices.

For forecasting purposes in the model, the statewide harvest used for the lower-valued salmon explanatory variable comes from a random draw of historic data in the same fashion as the forecasts of Bristol Bay salmon harvests.

Coho Salmon

Coho salmon represent a very small component of the Bristol Bay salmon catch. Over the 1975-2003 time period, coho salmon represented about 1.1% of the total pounds and 0.9% of the ex-vessel gross earnings obtained from the Bristol Bay salmon fisheries.

The peak of the coho harvest occurs well after the peak of the sockeye harvest, hence tending to benefit mostly local participants.

Coho salmon have become an important farmed salmon species. Worldwide farmed production of coho salmon is now considerably greater than the production of wild coho salmon.[32] As a result, the coho ex-vessel price is no longer significantly related to levels of wild coho production in Alaska. The falling price of the farmed coho substitute has likely impacted wild coho ex-vessel prices in a similar fashion as they have impacted prices for wild sockeye.

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[31] The estimated equation for the natural logarithm of the pink ex-vessel price measured in real 2003 dollars is as follows:

$$\text{LN\_R03\_BB\_P440\_XVP} = \underset{(2.13)}{23.05510} + \underset{(2.90)}{.82960}\ \text{LN\_R03\_BB\_S420\_XVP} - \underset{(-2.31)}{1.25826}\ \text{LN\_SW\_LVALUE\_LBS}$$

R-Sq = .6690; adjusted R-sq = .6323; number of observations = 21; degrees of freedom =18; Durbin-Watson statistic = 1.645 (no serial correlation). The numbers in parentheses are T-values.
Where:

LN_R03_BB_P440_XVP	=	The natural logarithm of the Bristol Bay pink salmon ex-vessel price measured in real 2003 dollars.
LN_R03_BB_S420_XVP	=	The natural logarithm of the Bristol Bay sockeye salmon ex-vessel price measured in real 2003 dollars.
LN_SW_LVALUE_LBS	=	The natural logarithm of the statewide harvest of pink and chum salmon measured in dollars.

[32] For example, in 2001 worldwide farmed salmon production of coho salmon was estimated to be 151,286 metric tons, while the worldwide wild coho salmon harvest was estimated to be 21,386 metric tons.

The coho salmon ex-vessel price equation used the natural logarithm of the coho ex-vessel price, measured in real 2003 constant-value dollars as the dependent variable. Only one explanatory variable was used in the equation; namely, the natural logarithm of sockeye ex-vessel price measured in real 2003 constant-value dollars. The estimated coefficient was positive as anticipated and highly significant. The coefficient suggests that, *ceteris paribus*, coho salmon prices will be positively associated with sockeye salmon prices.[33]

Chinook Salmon

Chinook salmon are a small component of the Bristol Bay salmon catch. Over the 1975-2003 time period, chinook salmon represented about 1.4% of the total pounds and 1.4% of the ex-vessel gross earnings obtained from the Bristol Bay salmon fisheries. The peak of the chinook harvest occurs well before the peak of the sockeye harvest, hence tending to benefit mostly local participants.

The chinook salmon ex-vessel price equation used the natural logarithm of the chinook salmon ex-vessel price, measured in real 2003 constant-value dollars as the dependent variable. Only one explanatory variable was used in the equation: the natural logarithm of sockeye ex-vessel price measured in real 2003 constant-value dollars. The estimated coefficient was positive as anticipated and highly significant. The coefficient suggests that, *ceteris paribus*, chinook salmon prices will be positively associated with sockeye salmon prices.[34]

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[33] The estimated equation for the natural logarithm of the coho ex-vessel price measured in real 2003 dollars is as follows:

$$\underset{}{LN\_R03\_BB\_C430\_XVP} = \underset{(-7.96)}{-.49804} + \underset{(7.47)}{.95332}\ LN\_R03\_BB\_S420\_XVP$$

R-Sq = .7462; adjusted R-sq = .7329; number of observations = 21; degrees of freedom =18; Durbin-Watson statistic = 1.095 (serial correlation). The numbers in parentheses are T-values.
Where:

LN_R03_BB_C430_XVP = The natural logarithm of the Bristol Bay coho salmon ex-vessel price measured in real 2003 dollars.
LN_R03_BB_S420_XVP = The natural logarithm of the Bristol Bay sockeye salmon ex-vessel price measured in real 2003 dollars.

Note that the Durbin-Watson statistic indicates positive serial correlation of the residuals. For forecasting purposes, the authors decided to use the ordinary least squares estimated equation.

[34] The estimated equation for the natural logarithm of the chinook ex-vessel price measured in real 2003 dollars is as follows:

$$LN\_R03\_BB\_K410\_XVP = \underset{(-4.06)}{-.26708} + (\underset{(7.26)}{.97489}\ LN\_R03\_BB\_S420\_XVP)$$

R-Sq = .7451; adjusted R-sq = .7212; number of observations = 21; degrees of freedom =19; Durbin-Watson statistic = .848 (serial correlation). The numbers in parentheses are T-values.
Where:

LN_R03_BB_K410_XVP = The natural logarithm of the Bristol Bay chinook salmon ex-vessel price measured in real 2003 dollars.
LN_R03_BB_S420_XVP = The natural logarithm of the Bristol Bay sockeye salmon ex-vessel price measured in real 2003 dollars.

Note that the Durbin-Watson statistic indicates positive serial correlation of the residuals. For forecasting purposes, the authors decided to use the ordinary least squares estimated equation.

Summary of Ex-Vessel Price Forecasts for Other Salmon Species

In summary, ex-vessel price forecasting equations were developed for the other salmon species using historic data. All of the equations took advantage of the fact that ex-vessel prices of all salmon species have been impacted by the dramatic growth in farmed salmon. This has led to an increase in the positive association among the ex-vessel prices for the different species over time.[35] The forecasting equations for ex-vessel prices measured in real 2003 dollars for the other salmon species all used the natural logarithm of the sockeye ex-vessel price, measured in real 2003 dollars, as an explanatory variable.

4.1.d Forecasts of Average Gross Earnings per Permit

The simulation model uses a straightforward methodology for forecasting the total gross earnings in the Bristol Bay drift gillnet fishery in a year. The harvests for a forecast year are drawn randomly from 1978 through 2003. Real 2003 ex-vessel prices are then estimated using the ex-vessel price forecasting equations and other mechanisms discussed in the subsections above. Total gross earnings for the forecast year in real 2003 "constant-value" dollars are then calculated by multiplying the ex-vessel price estimates for each species by the total pounds harvested for the species.[36]

Average gross earnings per permit depend upon total gross earnings in the fishery and the number of permits in the fishery.[37] In the model, average gross earnings per permit is calculated by dividing the total gross earnings by the number of permits. The model compares results in 100-permit increments.

4.1.e Forecasts of Average Total Costs in the Fishery

Forecasting of average total costs per permit in the simulation model utilized an eclectic methodology. The methodology was used because of the limitations of the cost data. Data on fishing costs are not collected by the State of Alaska in the normal data gathering processes for administrative and management purposes. As discussed in Chapter 3, CFEC's research staff conducted a survey in 2002 that gathered needed data on individual operating costs, investments, and net returns. Two reports on this survey have previously been released and are available on the CFEC website.[38]

The survey collected some cost data for the years 2001 and prior. However, the survey data, if used alone, were inadequate to make reasonable estimates of average costs and returns over the entire time period. Instead, the data from individual surveys were merged to CFEC data on the relevant fishing operations; this enhanced data set was then used to develop models for specific cost categories shown in Chapter 3. Specific costs were usually modeled

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[35] Positive correlation among real ex-vessel prices has probably always existed for other reasons. Prices between the species can differ for a variety of reasons, including perceived quality differences.
[36] A very small amount of non-salmon harvest has been caught and sold in the fishery in some years. For purposes of the simulation model, these harvests have been ignored.
[37] For purposes of this exercise, no distinction is drawn between permits issued and permits fished.
[38] See Carlson, *2002 Survey of Bristol Bay Salmon Drift Gillnet Permit Holders: Preliminary Summary of Responses*, and Carlson and Schelle, *2002 Survey of Bristol Bay Drift Gillnet Permit Holders: A Review of Survey Methodology and Implementation Procedures.*

as a function of vessel attributes, permit holder attributes, harvest, effort, and/or gross earnings.[39] These models were then used to generate estimates of the different specific costs incurred by each permit fished over the 1983-2003 time period. The results were shown in Tables 3.2.a and Table 3.2.b in Chapter 3. The total cost for an operation was simply the sum of the different specific costs incurred by the operation.

For the simulation model, a single equation was needed to generate estimates of the total costs for an average fishing operation as harvests, gross earnings, and the number of permits changed. To develop a forecasting equation for total costs, the authors used the estimates of total costs (measured in real 2003 dollars) for each fishing operation as the dependent variable. The observations used to estimate the total cost forecasting equation came from the 1983 through 2003 time period, and were confined to permits that were used by a single person fishing a single vessel during the year.[40]

The total cost forecasting equation was modeled partially as a cubic cost function with respect to total pounds harvested.[41] Since crew shares for crew other than the skipper are a function of gross earnings, the operation's gross earnings was added as an explanatory variable.[42] Other explanatory variables include the total weeks with landings, the horsepower of the vessel, and dummy variables for vessels with wood hulls or fiberglass hulls.[43]

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[39] This methodology for estimating costs by combining available ancillary data on a fishing operation with survey data on the operation is somewhat similar to a method used previously in the Gulf of Mexico shrimp fishery. See R.D. Funk, W.L. Griffin, J.W. Mjelde, T. Ozuna, JR., and J.M. Ward. *Imputing Fishing Costs and Returns,* in Marine Resource Economics, Vol. 13, No. 3, Fall 1998, 13pp.

[40] The vast majority of Bristol Bay permits are fished by a single person using a single vessel during the year. However, there are some permits that are fished by more than one person during the year. For example, one person may fish and record a landing on a permit, then in mid-season they might emergency transfer the permit to another person who also records landings on the permit. There are also cases where different vessels are associated with a permit at different times during the year.

[41] The "goodness of fit" statistics should be viewed with caution. The equation was estimated using an "estimate" of the total costs of each operation generated in the fashion described above. This procedure eliminated much of the variation that would exist in actual total cost data if such data existed on each operation.

[42] The authors note that some other cost categories were positively related to gross earnings also. This may explain the magnitude of the coefficient obtained on the gross earnings variable.

[43] The total cost function estimated for the simulation model was as follows:

$$
\begin{aligned}
\text{R03 Total Costs} = \;& \underset{(45.83)}{6562.31497} + \underset{(385.64)}{(.30671\ \text{R03GE})} + \underset{(23.59)}{(.06034\ \text{lbs})} - \underset{(-7.47)}{(.000000111579\ \text{lbs}^2)} \\
& + \underset{(4.39)}{(.000000000000092185\ \text{lbs}^3)} + \underset{(150.52)}{(2236.83962\ \text{weeks})} + \underset{(132.66)}{(30.34912\ \text{hp})} \\
& - \underset{(-82.49)}{(7942.65967\ \text{DWOOD})} - \underset{(-23.62)}{(1548.89523\ \text{DFGLASS})}
\end{aligned}
$$

R-Sq = .9481; adjusted R-Sq = .9481; n=35454; degrees of freedom = 35445

Where:

R03 Total Costs	=	Total costs measured in real 2003 dollars.
R03GE	=	Gross earnings measured in real 2003 dollars.
Lbs	=	Pounds harvested.
Lbs^2	=	The square of pounds harvested.
Lbs^3	=	The cube of pounds harvested.
Weeks	=	Statistical weeks with landings
Hp	=	the horsepower of the vessel
DWOOD	=	a dummy variable that equals 1 if the vessel has a wood hull and 0 otherwise.
DFGLASS	=	a dummy variable that equals 1 if the vessel has a fiberglass hull and 0 otherwise.

Weeks with landings serves as a surrogate measure of the skipper's time spent at the fishery. Like pounds harvested, weeks with landings is probably also capturing other vessel-related costs that tend to increase the longer and harder a vessel is fished.

Horsepower is a surrogate measure of the vessel's fishing power. Vessels with greater fishing power may harvest more fish but they can also be more expensive to operate. The dummy variables for wood and fiberglass hulls are intended to capture cost differences between vessels with those hull types and vessels with aluminum hulls.

For purposes of forecasting average total costs in the future, the variables for vessel attributes were set at average values for the fleet during the 2003 season. The hull dummy variables were assigned the fraction of the fleet that had that hull type during 2003. The weeks with landings explanatory variable is generated from another equation based on the average pounds harvested per permit, the sockeye ex-vessel price, and the total harvest in the year.

4.2 Forecasts of Future Net Returns

This section provides forecasts of future economic returns from the simulation model. Three scenarios are used to bound the range for economic optimum numbers. There is a baseline case scenario which the authors consider most likely. There is also a "low ex-vessel price scenario" which contains lower ex-vessel price forecasts than in the baseline case. And finally, there is a "high ex-vessel price scenario" that contains higher ex-vessel price forecasts than in the baseline case.[44]

There are many uncertainties about the future, and the simulation model is particularly sensitive to forecasts of future ex-vessel prices. Thus, three scenarios are used, to highlight the impact that ex-vessel prices forecasts can have on forecasts of average economic profits per permit. The sensitivity of the model to ex-vessel price estimates reflects the simple reality that ex-vessel prices and gross earnings are directly related. For any given harvest level, a percentage increase in ex-vessel prices will lead to an increase in gross earnings of exactly the same percentage. Similarly, a percentage decrease in ex-vessel prices will lead to a decrease in gross earnings of exactly the same percentage.

[44] The scenarios used herein focus on ex-vessel prices largely because the results are very sensitive to forecasts of ex-vessel prices, and future ex-vessel prices are a major source of uncertainty. However, changes in other parts of the model could also lead to substantial differences in estimates of the future rates of economic return for a given level of permits. The estimated cost function for an operation is an example. The model shows an increase in the costs of an operation as the pounds harvested and gross earnings increase. The average costs of a fishing operation tend to increase as the fleet size is reduced, since average pounds per operation and average gross earnings per operation are higher. However, some of the costs per operation may not increase as rapidly as forecast herein as the size of the fleet is reduced. For example, at higher levels of gross earnings the crew share as a percentage of gross earnings might decline. Alternatively, a decline in the congestion in the fishery as the fleet size is reduced may reduce the race for the fish and reduce some costs associated with the race for the fish; i.e., less fuel consumed battling for position, fewer repairs to the vessel and gear due to collisions, and etc. If these things occurred, the increase in the average cost of an operation as the fleet size is reduced could be lower than shown herein and the average profits for a given level of permits would be higher. However, should economic profits occur in the fishery there may be more investment in excess fishing capacity, raising costs further in the future. The reader should note that while the costs associated with a single fishing operation may increase as the fleet size is reduced for reasons cited above, the model is still forecasting a very large decline in total harvesting costs for the fishery as the result of reductions in fleet size. Reducing the number of operations leads to a very large decline in total harvesting costs, even when cost increases are forecasted for the remaining operations in the fishery. The decline in total harvesting costs is needed to achieve profitability.

To make the three scenarios strictly comparable, all other factors that could lead to minor differences between the scenarios are held constant. As noted earlier, forecasts of future harvests are drawn randomly from the distribution of harvests over the 1978 through 2003 time period. The sequence of random draws depends upon the initial random number seed. While different initial random number seeds do not lead to dramatic differences in the distribution of means over 100 simulations, the authors chose to use the same random number seed in all three scenarios so there would be no differences between the results of the three scenarios due to the choice of a random number seed. Essentially, all three scenarios are looking at exactly the same year-to-year harvest sequences in each "sample" of 25 years.[45]

Similarly, the three scenarios are looking at the same sequences of random variation from the explanatory variable for the Japanese wholesale price of farmed coho salmon. By holding these sequences constant across scenarios, the differences in the results from the three scenarios are due exclusively to the differences in the ex-vessel price forecasts across the scenarios.

Table 4.1 in the previous section shows how ex-vessel prices changed over the time period of limited entry, in both nominal and real dollars. Table 4.2 below focuses on sockeye ex-vessel prices, dividing the overall time period into three periods by decade. Sockeye ex-vessel price averages were calculated in both nominal and real 2003 dollars for each time period, where the averages are the simple averages of the annual sockeye ex-vessel prices during the period.

Table 4.2. Estimated Average Bristol Bay Sockeye Salmon Ex-Vessel Prices By Decade

	Nominal Average Price Per Pound	Real Average Price Per Pound
1980-89	1.03	1.62
1990-99	0.92	1.11
2000-03	0.52	0.54

Real prices are in 2003 dollars, using the Anchorage CPI

Both Table 4.1 and Table 4.2 illustrate that in real terms, ex-vessel prices have been trending downward for sockeye and for other salmon species. The data indicate that the average real

[45] SAS software was used to generate the random number sequences for the scenarios reported herein. The historic years of harvests used for forecast years were drawn ultimately from a uniform distribution with an equal probability of selection using the "Call RANUNI" routine with an initial random number seed of 7291853. The random variations from the mean Japanese wholesale price for frozen farmed coho were drawn ultimately from a standard random normal distribution using the "Call RANNOR" routine with an initial random number seed of 4876337. The sequences were held constant for all three scenarios.

Bristol Bay sockeye ex-vessel price from 2000-2003 is 51% lower than the real sockeye ex-vessel average price over the 1990-1999 time period; it is 67% lower than the real sockeye ex-vessel average price during the 1980-1989 time period. This, in part, reflects a decline due to the growth of farmed salmon and trout and the concomitant drop in prices of these farmed substitutes over the same time period. The decline in ex-vessel prices has impacted gross earnings and profitability. The forecasting equations used in the simulation model reflect the reality of the decline in the price of farmed substitutes for wild salmon.

4.2.a Baseline Scenario

The "Baseline Scenario" incorporates the assumptions discussed in the introduction to this section. The baseline scenario is the intermediate scenario and the one that the authors believe is most likely. This scenario results in average "real" ex-vessel sockeye prices over 100 simulations that are slightly below any prices observed over the 1975-2003 time period.[46]

With respect to the ex-vessel price equations, the baseline scenario forecasts ex-vessel prices directly from the models discussed earlier. Again, each of these scenarios could change somewhat with the choice of the initial random seeds, but the distribution of the simulation means over 100 simulations that forecast 25 years out into the future does not change dramatically based on the initial random seed. Therefore, results here will focus on the distribution of the means from this baseline scenario.

Table 4.2.a-1. Baseline Scenario: Ex-Vessel Prices by Salmon Species. Mean Prices From the Distribution of Sample Means of 100 Simulations

Mean Prices are in Real 2003 Dollars per Pound

Species	Overall Mean	Minimum Mean	Maximum Mean
Sockeye	$ 0.41	$ 0.35	$ 0.47
Chinook	$ 0.32	$ 0.27	$ 0.36
Coho	$ 0.26	$ 0.22	$ 0.29
Chum	$ 0.13	$ 0.10	$ 0.17
Pink	$ 0.09	$ 0.06	$ 0.11

Table 4.2.a-1 provides statistics on the distribution of the means of the ex-vessel prices, measured in real 2003 "constant-value" dollars from each of the 100 simulations that forecast 25 years out into the future. The table provides the overall average mean over the 100 simulations and the minimum and maximum means that resulted from any single twenty-five

[46] For simulation purposes, all dollars will be real 2003 "constant-value" dollars. Doing the forecast in constant-value dollars eliminates the need to forecast general price inflation. To the extent that general price inflation occurs in the future, the prices in nominal dollars in the future would be higher than those reported herein.

year simulation. The means reported herein are simple averages for the 25 year period and not weighted averages.[47]

As can be seen, the overall mean of the real 2003 sockeye ex-vessel price over all 100 simulations is $.41 per pound. The minimum average price that occurred from any single simulation of 25 years was $.35 per pound; the maximum average price that occurred from any single simulation of 25 years was $.47 per pound.

In real terms, the sockeye ex-vessel overall mean price from the baseline scenario is slightly lower than any price observed over the entire 1975-2003 time period in this baseline scenario. Historically, the lowest sockeye ex-vessel price over the time period occurred in 2001 at $.44 per pound, measured in real 2003 dollars.[48] The maximum mean sockeye ex-vessel price appearing in any single simulation is only slightly higher than the lowest "real 2003" ex-vessel price observed historically.

The overall means of the real 2003 ex-vessel prices for the other salmon species over all 100 simulations are also on the low end of real prices observed over the 1975-2003 time period. The forecasts emanating from the baseline scenario reflect the assumption that worldwide production of farmed salmon and trout will likely keep the wholesale prices of farmed substitutes of wild Alaska salmon low in the future.

The reader should note that the minimum and maximum observed in Table 4.2.a-1 represent the minimum and maximum "mean prices" that occurred in any of the 100 simulations. Again, each simulation extends 25 years out into the future and the "mean price" for any simulation is the simple average of the ex-vessel prices forecasted for each of the twenty-five years. An ex-vessel price that occurs for any single year in a simulation could be well above or well below the mean price for that simulation.

Table 4.2.a-2. Baseline Scenario: Frequency Distribution of Sockeye Ex-Vessel Prices From 100 Simulations of 25 Years, Measured in Real 2003 Dollars per Pound.

Price Range	Frequency	Percent	Cumulative Percent
$.15 to $.19	12	0.48	0.48
$.20 to $.29	374	14.96	15.44
$.30 to $.39	856	34.24	49.68
$.40 to $.49	682	27.28	76.96
$.50 to $.59	359	14.36	91.32
$.60 to $.69	152	6.08	97.40
$.70 to $.79	55	2.20	99.60
$.80 to $.89	9	0.36	99.96
>= $.90	1	0.04	100.00

[47] Again, the results will vary somewhat depending upon the initial random number seeds used in the model. However, the results over any 100 simulations are similar to those reported here.
[48] $.42/lb measured in 2001 dollars.

Table 4.2.a-2 provides a frequency distribution of all the forecasted sockeye ex-vessel prices, again measured in real 2003 dollars. These ex-vessel prices are those that occurred in any forecast year in any simulation. Thus out of the 100 simulations of 25 years each, there are 2,500 ex-vessel price forecasts for sockeye salmon.

The table shows that the price that occurs in any forecast year could be above or below the minimum and maximum mean price for the 100 simulations reported in Table 4.2.a-1. The reader should note that the highest sockeye ex-vessel price in any forecast year in this baseline scenario was $.92 per pound, measured in real 2003 dollars.

Table 4.2.a-3 provides results from the baseline scenario on how average pounds per permit, average gross earnings per permit, average costs per permit, and average profits per permit vary depending upon the number of permits in the fishery. The table is generated assuming that all of the permits would be fished. Again, this table is reporting on the distribution of means from 100 simulations of 25 years each.

As can be seen, under the baseline scenario assumptions, it would take a substantial reduction in the number of permits to achieve a reasonable average rate of economic return considering time fished and necessary investments in vessel and gear. Recall that economic profits, as defined herein, occur only after all costs have been subtracted from gross earnings, including the opportunity cost of the skipper's time and the opportunity cost of the investment in vessel and gear. A reasonable average rate of economic return is defined herein to mean achieving, on average, at least a positive economic profit.[49]

Based on the overall means from 100 simulations of the baseline scenario, it would take a reduction to around 900 permits to achieve positive economic profits on average over the next 25 years. Even at 900 permits under the baseline scenario, some of the simulations of 25 years into the future under baseline assumptions still suggest negative average economic profits. The estimated overall means for 900 permits from the baseline scenario simulations are 141,819 average pounds per permit, $51,204 average gross earnings per permit, and $542 average economic profits per permit.

Recall that these estimates assume the entire harvest will be taken, and that all permits will be fished. Under those assumptions, there will be years in which average economic profits per permit are negative and years in which average profits per permit would be positive. In reality, some permits will probably not be fished when there are expectations of poor economic returns. Permit holders who opt not to fish will be trying to minimize their losses by not fishing.[50] By not fishing, they would also increase the economic returns of the remaining permit holders in the fishery. When some permit holders opt not to fish, the overall economic profits per permit fished would be higher than shown in the simulations.[51]

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[49] Using the economic profit measure defined herein, an economic profit of zero is sometimes termed a "normal profit" in the economics literature.
[50] Some costs are incurred even if one opts not to fish. Examples would be costs such as storage expenses, property tax on the vessel, and the opportunity cost of the investment in the vessel.
[51] The reader again should note that the estimates of historic average economic profits, shown in Chapter 3, are average economic profits per permit fished. In some recent years, substantial percentages of permits were not fished.

Harvesting the entire available surplus in future years may also be problematic. The overall estimated 141,819 average pounds per permit for 900 permits is above any average harvest per vessel occurring in the historic data. However, it is not above the maximum amounts harvested by individual vessels historically. At this point, the authors are assuming that the Department of Fish and Game could adjust fishing times so that the smaller fleet could harvest the available surplus. The Board of Fisheries could also alter regulations if harvesting the available surplus becomes a problem.

In summary, under the assumptions used in the baseline scenario including the ex-vessel price estimates, the number of permits would need to be reduced to about 900 to achieve reasonable average rates of economic return in the future.

Table 4.2.a-3. Baseline Scenario: Average Pounds per Permit, Average Gross Earnings, Average Costs, and Average Economic Profits, By Number of Permits.
Distribution of Means From 100 Simulations of 25 Years into the Future

Number of	Pounds			Earnings			Costs			Profits		
Permits	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
500	255,274	200,931	313,897	$92,168	$79,713	$103,470	$66,442	$61,074	$71,567	$25,726	$18,639	$31,904
600	212,728	167,442	261,581	$76,807	$66,427	$86,225	$60,728	$56,003	$65,248	$16,078	$10,424	$21,061
700	182,338	143,522	224,212	$65,834	$56,938	$73,907	$56,522	$52,243	$60,623	$9,313	$4,695	$13,501
800	159,546	125,582	196,186	$57,605	$49,820	$64,669	$53,268	$49,324	$57,062	$4,337	$496	$7,923
900	141,819	111,628	174,387	$51,204	$44,285	$57,484	$50,663	$46,982	$54,222	$542	-$2,697	$3,658
1,000	127,637	100,465	156,949	$46,084	$39,856	$51,735	$48,519	$45,052	$51,890	-$2,435	-$5,196	$306
1,100	116,034	91,332	142,680	$41,895	$36,233	$47,032	$46,717	$43,432	$49,930	-$4,823	-$7,199	-$2,339
1,200	106,364	83,721	130,790	$38,403	$33,214	$43,113	$45,176	$42,046	$48,254	-$6,773	-$8,915	-$4,488
1,300	98,182	77,281	120,730	$35,449	$30,659	$39,796	$43,840	$40,846	$46,802	-$8,390	-$10,353	-$6,277
1,400	91,169	71,761	112,106	$32,917	$28,469	$36,954	$42,668	$39,795	$45,529	-$9,751	-$11,561	-$7,788
1,500	85,091	66,977	104,632	$30,723	$26,571	$34,490	$41,631	$38,868	$44,402	-$10,908	-$12,589	-$9,075
1,600	79,773	62,791	98,093	$28,803	$24,910	$32,334	$40,705	$38,044	$43,390	-$11,902	-$13,471	-$10,182
1,700	75,081	59,097	92,323	$27,108	$23,445	$30,432	$39,872	$37,307	$42,477	-$12,764	-$14,235	-$11,143
1,800	70,909	55,814	87,194	$25,602	$22,142	$28,742	$39,120	$36,644	$41,648	-$13,518	-$14,903	-$11,986
1,900	67,177	52,877	82,604	$24,255	$20,977	$27,229	$38,437	$36,044	$40,893	-$14,183	-$15,491	-$12,729
2,000	63,818	50,233	78,474	$23,042	$19,928	$25,868	$37,815	$35,498	$40,201	-$14,773	-$16,013	-$13,390

4.2.b High Ex-Vessel Price Scenario

This subsection reports the results of the "High Ex-Vessel Price Scenario." This scenario uses assumptions about future ex-vessel prices that are substantially higher than the baseline case.

There are many theories that might lead to higher ex-vessel prices than are forecast in the baseline case. One theory would be that the wholesale prices for farmed salmon will wind up at higher levels than one might expect based on the baseline case. Another theory might be that campaigns to educate the public on the benefits of wild salmon as opposed to farmed salmon will lead to a greater premium in the market for wild salmon. A third theory might be that new, more profitable, outlets or product forms for Bristol Bay sockeye will be found and ex-vessel prices will be positively impacted. These and other theories could be generated to suggest that ex-vessel prices in the future could be higher than forecast in the baseline case.[52]

This "high ex-vessel price scenario" assumes that ex-vessel prices for sockeye will be 30% higher than the price predicted by the sockeye forecasting equation. The higher sockeye price then leads to higher prices for the other salmon species. The result is a forecast of a more profitable fishery for all levels of permits relative to the baseline case.

Table 4.2.b-1 provides statistics on the distribution of the means of the ex-vessel prices under the "high ex-vessel price scenario" from each of the 100 simulations of 25 years out into the future. Again, these mean ex-vessel price estimates are in real 2003 "constant-value" dollars. The table provides the overall average mean over the 100 simulations, and the minimum and maximum means that resulted from any single 25-year simulation. The means reported herein are simple averages for the 25-year period; they are not weighted averages.[53]

Table 4.2.b-1. High Price Scenario: Ex-Vessel Prices by Salmon Species. Mean Prices From the Distribution of Sample Means of 100 Simulations

Mean Prices are in Real 2003 Dollars per Pound

Species	Overall Mean	Minimum Mean	Maximum Mean
Sockeye	$ 0.54	$ 0.45	$ 0.61
Chinook	$ 0.42	$ 0.35	$ 0.47
Coho	$ 0.34	$ 0.29	$ 0.38
Chum	$ 0.16	$ 0.13	$ 0.20
Pink	$ 0.11	$ 0.08	$ 0.13

[52] The reader should note that there are also theories on why ex-vessel prices will be lower than those forecast in the baseline case.
[53] Again, the results will vary somewhat depending upon the initial random number seeds used in the model. However, the results over any 100 simulations are similar to those reported here.

As can be seen, in the high ex-vessel price scenario the overall mean of the real 2003 sockeye ex-vessel price over all 100 simulations is $.54 per pound. The minimum average price that occurred from any single simulation of 25 years was $.45 per pound and the maximum average price that occurred from any single simulation of 25 years was $.61 per pound. These outcomes can be contrasted with the results from the baseline case.

In real terms, the overall mean sockeye ex-vessel price from the high ex-vessel price scenario is roughly equal to the real average sockeye ex-vessel price during the 2000-2003 time period. However, the overall mean sockeye ex-vessel price is still well below historic means that occurred during the decades of the 1980's and 1990's.

The overall means of the real 2003 ex-vessel prices for the other salmon species over all 100 simulations are also within the range of prices observed for each species over the 2000-2003 period. However, these overall means are still low relative to average prices observed in the decades of the 1980's and 1990's. Therefore, the high ex-vessel price scenario is still impacted by the assumption that the large worldwide production of farmed salmon and trout will continue and will likely keep the wholesale prices of farmed substitutes for Alaska wild salmon relatively low in the future.

Note the minimum and maximum observed in Table 4.2.b-1 represent the minimum and maximum "mean prices" that occurred in any of the 100 simulations. Again, each simulation extends 25 years into the future and the "mean price" for any simulation is the simple average of the ex-vessel prices forecasted for each of the 25 years. An ex-vessel price that occurs for any single year in a simulation could be well above or below the mean price for that simulation.

Table 4.2.b-2. High Price Scenario: Frequency Distribution of Sockeye Ex-Vessel Prices From 100 Simulations of 25 Years, Measured in Real 2003 Dollars per Pound.

Price Range	Frequency	Percent	Cumulative Percent
$.15 to $.19	0	0.00	0.00
$.20 to $.29	47	1.88	1.88
$.30 to $.39	410	16.40	18.28
$.40 to $.49	659	26.36	44.64
$.50 to $.59	600	24.00	68.64
$.60 to $.69	384	15.36	84.00
$.70 to $.79	215	8.60	92.60
$.80 to $.89	109	4.36	96.96
>= $.90	76	3.04	100.00

Table 4.2.b-2 provides results from the high ex-vessel price scenario on how average pounds per permit, average gross earnings per permit, average costs per permit and average profits per permit vary depending upon the number of permits in the fishery. The table is generated

assuming that all of the permits would be fished. Again, this table is reporting on the distribution of means from 100 simulations of 25 years each.

As can be seen, the high ex-vessel price scenario forecasts profitability for a higher level of permits than under the baseline case. However, it would still take a substantial reduction in the number of permits from current levels to achieve a reasonable average rate of economic return, considering time fished and necessary investments in vessel and gear. Recall that economic profits, as defined herein, occur only after all costs have been subtracted from gross earnings, including the opportunity cost of the skipper's time and the opportunity cost of the investment in vessel and gear.

Based on the overall means from 100 simulations of the high ex-vessel price scenario, it would take a reduction from the current 1,857 permits to around 1,200 permits to achieve positive economic profits on average over the next 25 years. Even at 1,200 permits under this scenario, some of the simulations of 25 years into the future still suggest negative average economic profits. The estimated overall means for 1,200 permits from the high price scenario simulations are 106,364 average pounds per permit, $49,849 average gross earnings per permit, and $974 average economic profits per permit.

Recall again that under all scenarios, these estimates assume that the entire harvest will be taken and that all permits will be fished. Under those assumptions, there will be years in which average economic profits per permit are negative and other years where average profits per permit would be positive. In reality, it is likely that some permits will not be fished when there are expectations of poor economic returns. Permit holders who opt not to fish will be trying to minimize their losses by not fishing.[54] By not fishing, they would also increase the economic returns of the remaining permit holders in the fishery. When some permit holders opt not to fish, the overall economic profits per permit fished would be higher than shown in the table.[55]

As mentioned above, the overall average pounds per permit for 1,200 permits is 106,364 pounds. This is within the average harvests per permit that have occurred in the historic data. At this point, the authors are assuming that the smaller fleet of 1,200 permits could harvest the available surplus. The Board of Fisheries could also alter regulations if harvesting the available surplus becomes a problem in years of high runs.

In summary, under the assumptions used in the high ex-vessel price scenario, the number of permits would need to be reduced to about 1,200 to achieve reasonable average rates of economic return in the future.

[54] Some costs are incurred even if one opts not to fish. Examples would be costs such as storage expenses, property tax on the vessel, and the opportunity cost of the investment in the vessel.
[55] The reader again should note that the estimates of historic average economic profits, shown in Chapter 3, are average economic profits per permit fished. In some recent years, substantial percentages of permits were not fished.

Table 4.2.b-3. High Price Scenario: Average Pounds per Permit, Average Gross Earnings, Average Costs, and Average Economic Profits, By Number of Permits. Distribution of Means From 100 Simulations of 25 Years into the Future

Number of	Pounds			Earnings			Costs			Profits		
Permits	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
500	255,274	200,931	313,897	$119,637	$103,453	$134,316	$75,055	$68,563	$81,198	$44,582	$34,890	$53,117
600	212,728	167,442	261,581	$99,698	$86,211	$111,930	$67,938	$62,278	$73,303	$31,760	$23,932	$38,627
700	182,338	143,522	224,212	$85,455	$73,895	$95,940	$62,728	$57,651	$67,552	$22,727	$16,244	$28,388
800	159,546	125,582	196,186	$74,773	$64,658	$83,947	$58,722	$54,083	$63,146	$16,052	$10,576	$20,883
900	141,819	111,628	174,387	$66,465	$57,474	$74,620	$55,531	$51,234	$59,649	$10,934	$6,239	$15,157
1,000	127,637	100,465	156,949	$59,819	$51,726	$67,158	$52,920	$48,901	$56,792	$6,899	$2,826	$10,636
1,100	116,034	91,332	142,680	$54,381	$47,024	$61,053	$50,735	$46,949	$54,402	$3,646	$75	$6,992
1,200	106,364	83,721	130,790	$49,849	$43,105	$55,965	$48,875	$45,288	$52,367	$974	-$2,182	$3,999
1,300	98,182	77,281	120,730	$46,014	$39,790	$51,660	$47,268	$43,854	$50,612	-$1,254	-$4,064	$1,505
1,400	91,169	71,761	112,106	$42,728	$36,947	$47,970	$45,865	$42,603	$49,079	-$3,138	-$5,656	-$598
1,500	85,091	66,977	104,632	$39,879	$34,484	$44,772	$44,628	$41,503	$47,727	-$4,749	-$7,036	-$2,378
1,600	79,773	62,791	98,093	$37,387	$32,329	$41,974	$43,526	$40,527	$46,518	-$6,139	-$8,277	-$3,916
1,700	75,081	59,097	92,323	$35,187	$30,427	$39,505	$42,539	$39,656	$45,431	-$7,351	-$9,358	-$5,258
1,800	70,909	55,814	87,194	$33,233	$28,737	$37,310	$41,649	$38,874	$44,447	-$8,416	-$10,307	-$6,438
1,900	67,177	52,877	82,604	$31,483	$27,224	$35,346	$40,843	$38,168	$43,553	-$9,359	-$11,148	-$7,484
2,000	63,818	50,233	78,474	$29,909	$25,863	$33,579	$40,109	$37,526	$42,738	-$10,200	-$11,897	-$8,417

4.2.c Low Ex-Vessel Price Scenario

This subsection reports the results of the "Low Ex-Vessel Price" scenario. This scenario assumes that future ex-vessel prices will be substantially lower than in the baseline case.

There are many theories that might lead to lower ex-vessel prices than those forecasted in the baseline scenario. One theory is that the cost of producing farmed salmon and trout will continue to fall and that wholesale prices for farmed salmon substitutes will decline to lower levels than those assumed in the baseline scenario. Another theory might be that publicity about contaminants in farmed salmon will have a negative impact on both farmed and wild salmon. These and other theories could be generated to suggest that future ex-vessel prices could be lower than those forecasted in the baseline case.[56]

This "low ex-vessel price scenario" assumes that ex-vessel prices for sockeye will be 30% lower than the price predicted by the sockeye forecasting equation. The lower sockeye price then leads to lower prices for the other salmon species. The end result is a forecast of a fishery that is less profitable for any given level of permits than is shown in the baseline scenario.

Table 4.2.c-1 provides statistics on the distribution of the means of the ex-vessel prices under the low ex-vessel price scenario from each of the 100 simulations of 25 years into the future. Again, these mean ex-vessel price estimates are in real 2003 "constant-value" dollars. The table provides the overall average mean over the 100 simulations and the minimum and maximum means that resulted from any single 25-year simulation. The means reported herein are simple averages for the 25-year period and not weighted averages.[57]

**Table 4.2.c-1. Low Price Scenario: Ex-Vessel Prices by Salmon Species.
Mean Prices From the Distribution of Sample Means of 100 Simulations**

Mean Prices are in Real 2003 Dollars per Pound

Species	Overall Mean	Minimum Mean	Maximum Mean
Sockeye	$ 0.29	$ 0.24	$ 0.33
Chinook	$ 0.23	$ 0.19	$ 0.26
Coho	$ 0.19	$ 0.16	$ 0.21
Chum	$ 0.10	$ 0.08	$ 0.13
Pink	$ 0.06	$ 0.05	$ 0.08

As can be seen, the overall mean of the real 2003 sockeye ex-vessel price over all 100 simulations of the low ex-vessel price scenario is $.29 per pound. The minimum average

[56] The reader should note that there are also theories on why ex-vessel prices could be higher than those forecast in the baseline case. A few of these were mentioned in subsection 4.2.b.
[57] Again, the results will vary somewhat depending upon the initial random number seeds used in the model. However, the results over any 100 simulations are similar to those reported here.

price that occurred from any single simulation of 25 years was $.24 per pound and the maximum average price that occurred from any single simulation of 25 years was $.33 per pound. These outcomes can be contrasted with the results from the baseline case.

In real terms, the sockeye ex-vessel overall mean price from this low ex-vessel price scenario is considerably lower than any price observed over the recent 1975-2003 time period. Historically, the lowest sockeye ex-vessel price over the time period occurred in 2001 at $.44 per pound measured in real 2003 dollars.[58] The overall mean sockeye ex-vessel price under the low scenario is substantially below even this lowest historic sockeye ex-vessel price.

The minimum and maximum observed in Table 4.2.c-1 represent the minimum "mean price" and the maximum "mean price" that occurred in any of the 100 simulations of the low ex-vessel price scenario. Again, each simulation extends 25 years into the future and the "mean price" for any simulation is the simple average of the ex-vessel prices forecasted for each of the 25 years. An ex-vessel price that occurs for any single year in a simulation could be well above or below the mean price for that simulation.

Table 4.2.c-2 provides a frequency distribution of forecasted sockeye ex-vessel prices under the low ex-vessel price scenario, again measured in real 2003 dollars. These ex-vessel prices are those that occurred in any forecast year in any simulation. Thus, out of the 100 simulations of 25 years each, there are 2,500 ex-vessel price forecasts for sockeye. The table shows that the price that occurs in any forecast year could be above or below the minimum or maximum mean price for the 100 simulations reported in Table 4.2.c-1.

Table 4.2.c-2. Low Price Scenario: Frequency Distribution of Sockeye Ex-Vessel Prices From 100 Simulations of 25 Years, Measured in Real 2003 Dollars per Pound.

Price Range	Frequency	Percent	Cumulative Percent
$.05 to $.14	24	0.96	0.96
$.15 to $.19	258	10.32	11.28
$.20 to $.29	1,189	47.56	58.84
$.30 to $.39	727	29.08	87.92
$.40 to $.49	247	9.88	97.80
$.50 to $.59	52	2.08	99.88
$.60 to $.69	3	0.12	100.00

Table 4.2.c-3 provides results from the low ex-vessel price scenario, showing how average pounds per permit, average gross earnings per permit, average costs per permit, and average profits per permit vary depending upon the number of permits in the fishery. The table is generated assuming that all of the permits would be fished. Again, this table reports on the distribution of means from 100 simulations of 25 years each.

[58] $.42/lb measured in 2001 dollars.

As can be seen, the assumptions for a low ex-vessel price scenario provide a forecast that indicates profitability will occur at a lower level of permits than under the baseline scenario. It would take a substantial reduction in the number of permits from current levels to achieve a reasonable average rate of economic return, considering time fished and necessary investments in vessel and gear. Recall that economic profits, as defined herein, occur only after all costs have been subtracted from gross earnings, including the opportunity cost of the skipper's time and the opportunity cost of the investment in vessel and gear.

Based on the overall means from 100 simulations of the low ex-vessel price scenario, it would take a reduction from the current level of 1,857 permits to around 600 permits to achieve, on average, positive economic profits over the next 25 years. Even at 600 permits under this scenario, some of the simulations of 25 years into the future under baseline assumptions still suggest negative average economic profits. The estimated overall means for 600 permits from the low price scenario simulations are 212,728 average pounds per permit, $53,883 average gross earnings per permit, $53,509 average costs per permit, and $374 average economic profits per permit.

Recall again under all scenarios, the estimates assume that the entire harvest will be taken, and that all permits will be fished. Under those assumptions, there will be years in which average economic profits per permit are negative and years in which average profits per permit would be positive. Again, it is likely that some permits will not be fished when there are expectations of poor economic returns. Permit holders who opt not to fish will be trying to minimize their losses by not fishing. By not fishing, they would also increase the economic returns of the remaining permit holders in the fishery. When some permit holders opt not to fish, the overall economic profits per permit fished would be higher than the profits indicated in the table.[59]

Harvesting the entire available surplus in future years may also be problematic. The estimated overall average pounds per permit for 600 permits is 212,728 pounds, which is above any average harvest per vessel that has occurred in the fishery since at least 1975. However, it is not above the maximum amounts harvested by individual vessels historically. At this point, the authors assume that the Department of Fish and Game could adjust fishing times so that the smaller fleet could harvest the available surplus. The Board of Fisheries could also alter regulations if harvesting the available surplus becomes a problem.

In summary, under the assumptions used in the low ex-vessel price scenario, the number of permits would need to be reduced to about 600 to achieve reasonable average rates of economic return in the future.

[59] The reader again should note that the estimates of historic average economic profits, shown in Chapter 3, are average economic profits per permit fished. In some recent years, substantial percentages of permits were not fished.

Table 4.2.c-3. Low Price Scenario: Average Pounds per Permit, Average Gross Earnings, Average Costs, and Average Economic Profits, By Number of Permits. Distribution of Means From 100 Simulations of 25 Years into the Future

Number of	Pounds			Earnings			Costs			Profits		
Permits	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
500	255,274	200,931	313,897	$64,660	$55,935	$72,582	$57,817	$53,573	$61,922	$6,843	$2,361	$10,942
600	212,728	167,442	261,581	$53,883	$46,612	$60,485	$53,509	$49,718	$57,182	$374	-$3,106	$3,697
700	182,338	143,522	224,212	$46,185	$39,953	$51,845	$50,307	$46,826	$53,685	-$4,121	-$6,873	-$1,356
800	159,546	125,582	196,186	$40,412	$34,959	$45,364	$47,806	$44,558	$50,969	-$7,394	-$9,615	-$5,037
900	141,819	111,628	174,387	$35,922	$31,075	$40,324	$45,787	$42,722	$48,787	-$9,865	-$11,800	-$7,758
1,000	127,637	100,465	156,949	$32,330	$27,967	$36,291	$44,112	$41,198	$46,982	-$11,783	-$13,495	-$9,873
1,100	116,034	91,332	142,680	$29,391	$25,425	$32,992	$42,694	$39,909	$45,453	-$13,303	-$14,837	-$11,555
1,200	106,364	83,721	130,790	$26,942	$23,306	$30,243	$41,473	$38,800	$44,136	-$14,531	-$15,919	-$12,919
1,300	98,182	77,281	120,730	$24,869	$21,513	$27,916	$40,406	$37,833	$42,987	-$15,537	-$16,803	-$14,045
1,400	91,169	71,761	112,106	$23,093	$19,977	$25,922	$39,466	$36,983	$41,974	-$16,374	-$17,537	-$14,986
1,500	85,091	66,977	104,632	$21,553	$18,645	$24,194	$38,630	$36,230	$41,073	-$17,077	-$18,153	-$15,780
1,600	79,773	62,791	98,093	$20,206	$17,480	$22,682	$37,880	$35,558	$40,258	-$17,674	-$18,675	-$16,456
1,700	75,081	59,097	92,323	$19,018	$16,451	$21,348	$37,203	$34,955	$39,519	-$18,185	-$19,122	-$17,037
1,800	70,909	55,814	87,194	$17,961	$15,537	$20,162	$36,588	$34,410	$38,845	-$18,627	-$19,507	-$17,541
1,900	67,177	52,877	82,604	$17,016	$14,720	$19,101	$36,029	$33,917	$38,228	-$19,013	-$19,843	-$17,982
2,000	63,818	50,233	78,474	$16,165	$13,984	$18,146	$35,517	$33,468	$37,662	-$19,352	-$20,138	-$18,370

4.3 Summary and Recommendation for Economic Optimum Numbers

This chapter described the economic simulation model that was used to forecast future average net economic returns in the Bristol Bay salmon drift gillnet fishery. The chapter has also provided forecasts of how future average net economic returns will vary depending upon the number of entry permits in the fishery and upon other assumptions about future fishery conditions. Results are provided on a "baseline scenario," a "high ex-vessel price scenario," and a "low ex-vessel price scenario." The results from the simulations under all three scenarios suggest that it will take a substantial reduction in the number of permits to achieve a reasonable rate of economic return for permit holders in the future.

The results of the simulation model are very sensitive to assumptions, particularly assumptions about future ex-vessel prices. Under the baseline scenario, the overall average sockeye ex-vessel price in real 2003 dollars over 100 simulations was about $.41 per pound. That is slightly lower than any sockeye ex-vessel prices observed over the 1975-2003 time period, when measured in real 2003 dollars. Under the baseline scenario, the overall average economic profits per permit only became positive when the number of permits in the fishery was reduced to 900 permits.[60]

Under the "high ex-vessel price scenario," the sockeye ex-vessel price forecasts are assumed to be 30% higher than those predicted by the forecasting equation. This results in increases in all ex-vessel prices over the baseline case. Under the high ex-vessel price scenario, the overall average sockeye ex-vessel price in real 2003 dollars over 100 simulations was about $.54 per pound. That is about equal to the average sockeye ex-vessel prices observed over the 2000-2003 time period, when measured in real 2003 dollars, but still lower than the average real sockeye ex-vessel prices observed in the 1980's and 1990's. Under the high ex-vessel price scenario, the overall average economic profits per permit became positive when the number of permits in the fishery was reduced to 1,200 permits.

Under the "low ex-vessel price scenario," the sockeye ex-vessel price forecasts are assumed to be 30% lower than those predicted by the forecasting equation. This results in decreases in the ex-vessel prices for all species over the baseline case. Under the low ex-vessel price scenario, the overall average sockeye ex-vessel price in real 2003 dollars over 100 simulations was about $.29 per pound. That is lower than any sockeye ex-vessel prices observed over the 1975-2003 time period, when measured in real 2003 dollars. Under the low ex-vessel price scenario, the overall average economic profits per permit became positive when the number of permits in the fishery was reduced to 600 permits.

To review, Standard One under AS 16.43.290(1) is concerned with achieving a "reasonable average rate of economic return." It reads as follows:

[60] Under each scenario, the model assumes that all permits are fished in each forecast year of each simulation. To the extent that some permits would not be fished in years of poor economic returns, average profits per permit would be higher than shown in the simulations. Average profits would also be higher if the costs for remaining fishing operations do not increase as greatly as predicted in the cost model. If costs due to congestion and the "race for the fish" are reduced as the fleet size is reduced, then the fishery might be more profitable than suggested by the simulations.

(1) the number of entry permits sufficient to maintain an economically healthy fishery that will result in a reasonable average rate of economic return to the fishermen participating in that fishery, considering time fished and necessary investments in vessel and gear;

"Economically healthy fishery" is further defined in AS 16.43.990(2) as follows:

(2)"economically healthy fishery" means a fishery that yields a sufficient rate of economic return to the fishermen participating in it to provide for, among other things, the following:

(A) maintenance of vessel and gear in satisfactory and safe operating condition; and

(B) ability and opportunity to improve vessels, gear, and fishing techniques, including, when permissible, experimentation with new vessels, new gear, and new techniques.

The outcomes of the three scenarios, in all cases, suggest that a large reduction in the number of permits would be needed in the future to achieve reasonable average rates of economic return for the permit holders. Reasonable average rates of return were defined to mean earning at least a positive economic profit, where economic profits occur only when earnings are sufficient to cover all costs, including the opportunity cost of the skipper's time and the opportunity cost of the investment in vessel and gear.

The baseline (intermediate) scenario is the one that the authors believe is most likely. However, there is much uncertainty about future prices and there are some factors that might result in either higher or lower ex-vessel prices than those suggested by the baseline case.

In 2002, Alaska's legislature changed the limited entry law to explicitly allow the optimum number to be a range.[61] Due to the uncertainty about the future and how much of a reduction will be needed to allow all future permit holders to participate and achieve positive economic profits as defined herein, the "economic optimum number" under Standard One should also be considered a range. While the authors believe that the baseline case is most likely, the bounds suggested by the low and high ex-vessel price scenarios could easily be possible. Thus, under Standard One, an economic optimum number range between 600 and 1,200 permits seems entirely appropriate given the uncertainty about the future.

[61] Early research efforts on optimum numbers suggest that CFEC was thinking of optimum numbers in terms of a range from the beginning. The change in the law makes it clear that the optimum number for a fishery can be a range.