FINAL REPORT:

STUDY OF SUPPLY EFFECTS ON SABLEFISH MARKET PRICE

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April 7, 2004

ACKNOWLEDGEMENTS

The research reported here was supported by funding from a group of people and organizations coordinated by Robert Alverson under the title “Eat on the Wild Side”. The list of supporters includes:

Alaskan Leader Fisheries
Atlantico
Canadian Sablefish Association
Cascade Mariner
Deep Sea Fishermen's Union
Fishing Vessel Owners' Association
G & W Fish Company, Inc.
Jubilee Fisheries
Mr Walt Sargent
Mark I, Inc.
M/V Icelander, Inc.
Mr. Gordon Jensen
NMFS-Juneau, NMFS-Seattle
North Pacific Fishery Management Council
North Pacific Fisheries Association, Inc.
Pacific States Marine Fisheries Commission
Seafood Producers Cooperative
University of Washington - Sea Grant
Washington Trollers Association
Yukon Delta Fisheries Dev. Association

In addition to funding support, the research effort was assisted by the willingness of numerous individuals in the aquaculture industry, fishing industry, government agencies, and universities to provide information, ideas, and viewpoints regarding the prospects for sablefish farming in the Pacific northwest and elsewhere. We owe thanks to Bob Alverson, Eric Wickham, Jim Anderson (University of Rhode Island), W. Craig Clarke and Rob Kronlund (Pacific Biological Station, Nanaimo, BC), William Daspit (Pacific States Marine Fisheries Commission), John Davidson and Terri Bonnet (Department of Fisheries and Oceans, Pacific Region), John Forster (Forster Consulting, Inc.), Jim Hastie and Michael Rust (NOAA Fisheries, Northwest Fisheries Science Center), Rob Saunders (Island Scallop), and Sunee Sonu (NOAA Fisheries, Southwest Regional Office).

I. INTRODUCTION

This is the final report of research sponsored by "Eat on the Wild Side", a consortium of sablefish harvesting industry groups, government agencies, and individuals listed above. The research questions covered by this research project include the following:

(1) How sensitive is the market price for sablefish (especially in the Japanese market for imports) to supply variation?

(2) Can we develop reliable quantitative predictions of price change due to specific supply shifts?

(3) Are sablefish prices affected by subtle product characteristics, such as fish size and origin?

(4) Is the development of sablefish farming operations in British Columbia likely to occur in the near future, and, if so, what is likely to be the average cost of production (or minimum viable price)?

(5) Will the sablefish farming technology be readily transferable to less developed nations, and which multi-national corporations are likely to be involved in the spread of sablefish farming?

These questions may prove crucial to the future of a sablefish fishing industry that has been remarkably successful in economic terms.

The sablefish fishery extends from California northward through British Columbia and the Gulf of Alaska to the Aleutian Islands and Bering Sea. Both trawl and fixed gear (longline and pot) harvest sablefish. The size, market value, and profitability of the fishery are illustrated in Tables 1 and 2 below. The gross ex-vessel value of the fishery, estimated at $141 million/year during 2000-2003, is bolstered by high wholesale prices sustained in the Japanese market. This places the sablefish fishery in the same league as such fisheries as the Alaska salmon fishery ($195 million ex-vessel value in 2003), the Bering Sea pollock trawl fishery ($209 million ex-vessel value in 2002), and Pacific halibut fishery ($161 million ex-vessel for US and Canada combined in 2002). Starting in 1990 the fixed gear sablefish fishery enjoyed improved profitability under various types of individual quota systems implemented by Canada's Department of Fisheries and Oceans in British Columbia, by the North Pacific Fishery Management Council in Alaska, and by the Pacific Fishery Management Council off Washington, Oregon, and California.

An Individual Vessel Quota (IVQ) program for longline fisheries harvesting halibut and sablefish was implemented in British Columbia in 1990. The North Pacific Fishery Management Council approved a similar Individual Fishing Quota (IFQ) program for halibut and sablefish longliners in Alaska in 1994. In each case, well-defined quota shares were established for specified vessel classes and for regions identified by the International Pacific Halibut Commission (for halibut) and the national authorities. These shares are transferable (within some limits) among qualified fishermen at negotiated (or brokered) prices.

The Pacific Fishery Management Council implemented a license limitation system for groundfish vessels along the Pacific Coast in 1994, and augmented this with a cumulative bi-monthly trip limit system for sablefish fixed gear vessels in 1997. The 164 permits receiving sablefish endorsements were assigned to “tiers” based upon historic sablefish landings levels, with each tier getting a specified fraction of the available total allowable catch (TAC) each year. Further, each permitted vessel was limited to a specified catch over any 2-month period (called a "bi-monthly trip limit"). Finally, in 2001, the system was modified to become more of an IFQ system in which the permit tiers were retained while permit holders were given a 7-month season, from April 1 to October 30, to harvest the quantities assigned to each permit. In 2003, for example, the quotas were 53,000 lbs (round weight) for tier 1 permits, 24,000 lbs for tier 2 permits, and 14,000 lbs for tier 3 permits. Permit holders are allowed to buy each other's permits and "stack" up to three of them.

The average market prices in Table 2 are estimated as follows. For Alaska, prices for IQ transfers in the few vessel categories and fishing areas, drawn from broker’s listing during 2003 in Pacific Fishing magazine, were used to calculate an average per pound of sablefish. The average IQ price is expressed per pound based upon the 2003 TAC allocation. For British Columbia, the IQ price is based upon price quotes from an important British Columbia broker. For west coast permits, Dock Street Brokers lists some Tier 3 permits offered for sale at about $100,000, and lists a Tier 2 permit for offer at $210,000. The permit values in Table 2 are based upon these price quotes and the author’s estimates for Tier 1 permits.

The estimated $460 million in asset value currently held in the form of IFQs, IVQs, and permits for sablefish fishing reflects a substantial increase in wealth of fishing firms that is largely due to the improved efficiency of fishing and marketing operations under the individual quota and permit systems. These systems have spawned a wide range of adaptations in the fishing industry, affected the timing and location of harvests, the quality and size of fish landed, and the relationships between fishing operations and export markets for sablefish. Generally, the high price and profitability of the sablefish fishery are also attributable to the limited supply of harvestable sablefish in the ocean and the high demand for frozen sablefish in the Japanese market. The high price is also a major factor attracting the interest of the aquaculture industry in developing sablefish culture as an alternative to Atlantic and Pacific salmon in the net-pens of British Columbia. A significant expansion in sablefish supply, through aquaculture development, could flood the market, force prices down, and ultimately threaten the value of existing sablefish harvesting rights and permits. These possible effects of expanded supply through aquaculture is a basic motivation for the research reported below.

Table 1. Size and Ex-vessel Value of the Sablefish Fishery by Region and Gear Type, annual average for 2000 - 2003. British Columbia dollar values are in real CD$, 2000 base year. Bering Sea, Gulf of Alaska, Pacific Coast, and Total values are in real US$, 2000 base year.

	Gear	British Columbia	Bering Sea	Gulf of Alaska	Pacific Coast	Total [a]
Average Price ($/lb)	line/pot	$ 3.84	$ 3.12	$ 3.30	$ 1.66	
	trawl	n/a	$ 1.40	$ 2.29	$ 1.16	
Quantity (metric tons)	line/pot	2,218.6	1,737.9	12,871.5	2,976.2	19,804.3
	trawl	0	286.5	1,099.2	2,294.8	3,680.4
Ex-vessel Value (1000$)	line/pot	$ 18,762	$ 11,946	$ 93,776	$ 10,900	$ 129,055
	trawl	0	$ 883	$ 5,544	$ 5,846	$ 12,273

[a] Total includes all 4 regions, with British Columbia values converted to US$.

Table 2. Number of participants in each longline fishery, typical prices for individual quotas, and estimated total asset value of individual harvest shares or “stackable permits”.

	British Columbia IVQ	Alaska IFQ	Wash., Ore., Calif. stackable permits	Total
No. Participants	30	876	164	1,070
Typical Market[a] Value	$17.65	$8.82	Tier 1: $400k Tier 2: $200k Tier 3: $100 k	
Overall Asset Value of IQs & Permits	$124 mil.	$308 mil.	$28 mil.	$460 mil

[a] Prices for IQs and permits derived from reports and quotes of various brokers. Tier 1 sablefish permit value is author’s estimate based upon size of 2-month trip limit. BC price derived from quoted price of $C 41 per pound of processed product as follows: divide by 1.48 to estimate price per round weight pound, then divide by Canada/US dollar exchange rate of 1.57.

II. HISTORY OF THE SABLEFISH FISHERY

Until approximately 1977, most of the Japanese demand for sablefish was met with fish caught by Japanese vessels operating in Alaskan waters. In the mid-1970's, nearly 300 Japanese vessels were operating off the coast of Alaska, harvesting numerous species of fish and shellfish (Elston *et al*., 1999). The Japanese sablefish harvest averaged 37,580 metric tons round weight from 1970 to 1975, peaking in 1972 at 56,255 mt (Sonu, 2000). Overall harvests of sablefish in the North Pacific also peaked at 66 thousand metric tons in 1972, then dropped to a low of 25 thousand mt in 1978, climbed back to another peak of 54.6 thousand mt in 1988, and then dropped steadily to about 22 thousand mt in 2001.

In the late 1970's, the U.S. Exclusive Economic Zone was implemented under the Magnuson Fishery Conservation and Management Act. "Americanization" of the sablefish fishery began in 1977, when the North Pacific Fishery Management Council began limiting Japanese activities in U.S. waters (Oliver, 1997). By 1985 the Japanese harvest was virtually zero (Table 3), and US and Canadian vessels took over the fishery. Some joint ventures between North American catcher vessels and Japanese processors operated between 1984 and 1991, but since then, the supply in the market has been North American based.

The fishery has three main management segments: Alaska, US Pacific Coast, and British Columbia. The two US fisheries are managed by the North Pacific Fisheries Management Council (Alaska), and the Pacific Fisheries Management Council (Pacific Coast). The Canadian fishery is managed by the Canada Department of Fisheries and Oceans. In 1990, the Canadian sablefish fishery converted to an Individual Vessel Quota (IVQ) system of allocation. There are currently about 30 active Canadian vessels with quota (Sablefish Advisory Committee, 2002). The Alaskan fishery followed a similar route in 1995 with an Individual Fishable Quota (IFQ) system. In 2002, there were 415 U.S. vessels participating in the Alaska IFQ fishery (NMFS, 2003). After the quota system was initiated, the fishing season changed from a derby that lasted only a few days, to a more evenly distributed effort lasting eight months. The management of the Pacific Coast fishery, largely a trawl fishery, is competitive among vessels in a license limited fishery.

Over the last 20 years, then, there have been major structural changes in the supply side of the sablefish market, along with a general decrease in the total allowable catch, and a general increase in sablefish prices (Figure 1). As more "rational" management of the fishery has become the norm in Canada and Alaska, the spread between ex-vessel price and Tokyo wholesale price has narrowed. This trend presents a challenge in forecasting how ex-vessel prices would be affected by future supply increases, as the distinct effects of IFQ's (which affected seasonal landing patterns and fisherman's bargaining power) is confounded in the historical record with the effects of changes in total quantity landed. We have addressed that difficulty, apparently successfully, as shown below.

Table 3. World Sablefish catches by country, 1958-2003 (metric tons round weight). 1958-1998 from Sonu (2000). 1999-2003 from Pacific States Marine Fisheries Commision (PacFIN) and Dept. of Fisheries and Oceans, Canada.

Year	USA	Canada	Japan	Other	Total
1958	2587	383	32	0	3002
1959	3990	362	393	0	4745
1960	5136	705	1861	0	7702
1961	3000	306	26182	0	29488
1962	4000	428	28381	0	32809
1963	2900	396	21582	0	24878
1964	3700	637	10252	400	14989
1965	3300	649	10103	700	14752
1966	3100	970	17516	3900	25486
1967	3200	591	22335	17000	43126
1968	2500	577	32762	16400	52239
1969	2200	391	43424	9800	55815
1970	2900	327	41151	6600	50978
1971	2700	327	44482	4700	52209
1972	5500	1104	56255	3200	66059
1973	6432	965	39053	2100	48550
1974	7028	503	35549	2300	45380
1975	8744	921	32242	1194	43101
1976	7895	796	30062	961	39714
1977	11510	1088	21844	1961	36403
1978	13240	831	9960	918	24949
1979	21973	2031	8666	1488	34158
1980	18705	3793	6736	1987	31221
1981	13023	3888	9167	1749	27827
1982	21403	4028	7350	1631	34412
1983	18575	4414	6964	1105	31058
1984	23565	3827	2282	466	30140
1985	28842	4268	187	152	33449
1986	38930	4668	43	97	43738
1987	46706	4719	11	39	51475
1988	48817	5770	62	35	54684
1989	44267	5493	5	2	49767
1990	40734	5038	0	0	45772
1991	37925	5531	0	0	43456
1992	34224	5029	0	0	39253
1993	35139	5310	0	0	40449
1994	32359	5202	0	0	37561
1995	31216	3838	0	8	35062
1996	28208	3009	0	502	31719
1997	25301	3651	0	0	28952
1998	20953	4500	0	0	25453
1999	21551	3647	na	na	25198
2000	22383	2603	na	na	24986
2001	20701	2454	na	na	23155
2002	19548	1752	na	na	21300
2003	22434	2065	na	na	24499

na = not available (but presumed zero).

In addition to the structural changes in the fishery, the Japanese economy has been in turmoil throughout most of the study period. There were two major recessions during the 1990's. The economy bottomed out in 1993 after a prolonged period of very rapid growth, recovering only moderately before growth again decelerated in 1997 (Bank of Japan, 2000). During this time, the yen depreciated significantly, putting downward pressure on the demand for imports. Despite these economic developments, consumer prices within Japan did not decrease as much as would be expected around the time of the 1997 recession (Bank of Japan, 2000). These unusual economic circumstances also contribute to the analytical challenge involved in forecasting future prices.

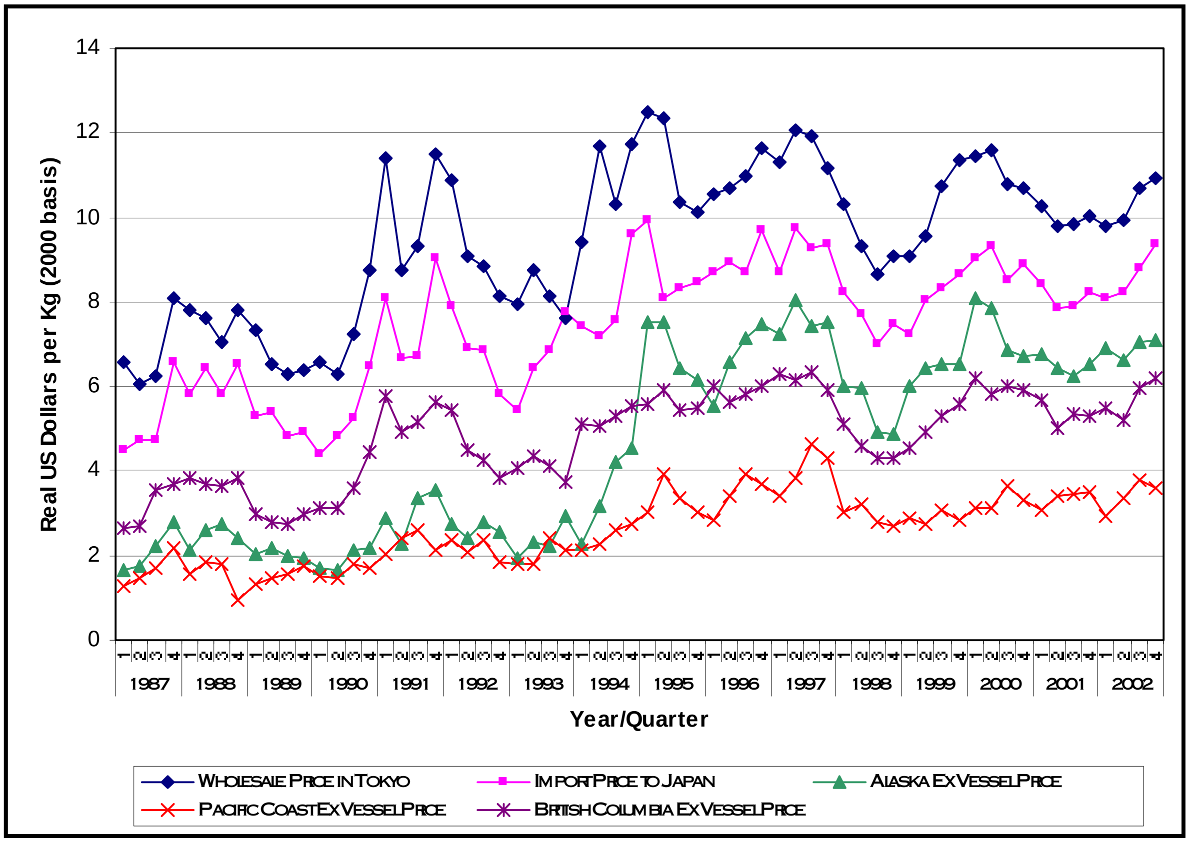

Figure 1. Real Sablefish Prices in US Dollars, at different market levels. Prices are for the fixed gear fishery (lines/pots).

III. SABLEFISH MARKET RESEARCH

The general structure of the sablefish market is described in Gislason & Associates (2001). Starting from the ideas described there, we devoted substantial effort to acquiring, cross-checking, coding and analyzing data pertaining to the sablefish fishery and markets. Much of the data was obtained from official US (NMFS, NPFMC) and Canadian (DFO) sources. Additional information concerning prices, imports and general economic conditions in Japan were obtained through Bill Atkinson's Market Newsletters, reports and additional data from Sunee Sonu at NMFS's Southwest Regional Office, and from Jim Hastie at NMFS's Northwest and Alaska Fishery Science Center.

A literature survey of fish market models published in economics journals and reports was conducted in concert with data collection efforts. This provided an overview of the kinds of considerations, variables, and econometric models that prevail in this area of research. In particular, the survey was important in guiding our approach to market modeling and price forecasting towards a multi-equation, simultaneous system estimation.

Combining the data sources with the simultaneous market model approach, we estimated and evaluated a wide range of alternative models, using the E-Views econometric software package. We selected the two main models described in this report, by applying both standard quantitative measures of statistical "fit", and practical concerns for realism and simplicity. These models answer the first question listed above, "How sensitive is market price to supply variation?", and much more. This quantitative model of sablefish markets will be written up for publication in an academic journal. This will assure that the results pass the test of peer review.

To forecast changes in the Tokyo price associated with increasing supply of sablefish (whether due to increasing TACs in the fishery or increasing production by fish farmers), we simply use the estimated demand models in combination with assumed constant levels of the other variables (the yen/dollar exchange rate and economic conditions in Japan) that influence market price in Tokyo. The models include equations that predict the effects of Tokyo price movements on ex-vessel prices in Alaska, British Columbia, and the US West Coast fisheries. From these, we can estimate the specific price effects in each of the main fishing areas.

During the process of researching the market models we found that we could not broadly answer the question concerning effects of subtle product characteristics on price due to data limitations. According to data in Sonu (2000), fish in the 1-2 pound class obtain prices about 2/3 of those for fish in the 5 pound and over class. While we have data showing price differentials among size classes of sablefish in the Tokyo Central Wholesale Market, we did not find corresponding information about the quantities of fish landed by size class, nor quantities of fish imported and sold in Japan by size class. Consequently, we could not estimate separate demand or price equations for size classes of sablefish. And we cannot determine whether or how much of the price variability observed in the data is attributable to variations in the size of fish caught and sold. Our forecasts effectively assume that increasing supply is distributed across fish sizes in a representative way. Consequently, we do not yet have a reliable way to forecast the effects of increasing supply in a particular size class. This could be a crucial gap in the forecasting approach if, for example, a major increase in supply is concentrated in a smaller size fish. If sablefish farmers should concentrate on fish in the smaller size class (for reasons of lower growing costs) the effect might be to differentially depress the price of those smaller fish.

A. Data Description and Preparation for Analysis:

Sablefish Landings and Landed Value

Quarterly U.S. landings and value data were obtained for the years 1981 through 2003, separated by gear and area. Monthly Canadian landings and value data were obtained for the years 1985 through 2002, separated by gear and product (dressed/round, frozen/fresh, etc.). As of this writing, the Canadian data for 2003 were only available as a preliminary annual total. All products were converted to their round weight equivalents (in kilograms), and gears were aggregated into fixed gear (*ie.* line or pot) and trawl. Ex-vessel prices for fixed gear and trawl were then calculated on a round-weight basis.

Japanese Sablefish Prices and Quantities

Sablefish wholesale prices and quantities are from the Tokyo Central Wholesale Market (TCWM). Between 1987 and 2002, the Tokyo Central Wholesale Market handled 40% of all sablefish imported by Japan, and therefore represents a significant proportion of the Japanese market. Because of this large market share, and because data are not available from other wholesale markets, the TCWM is taken to be representative of wholesale markets throughout Japan. (See Figure 2, below). The official Tokyo market data were not yet available for 2003, and so the Tokyo wholesale price for 2003 is calculated from biweekly published spot prices.

Monthly import prices and quantities were taken from the “Japanese Fishery Imports” reports published on the National Marine Fisheries Service’s “Japanese Market News” web site[1] and in Bill Atkinson’s News Report. Sablefish was not counted separately in Japanese import statistics until 1987, and was probably grouped with cod before that time. Both wholesale and import data were entered manually into spreadsheets.

Total Allowable Catch (TAC)

We added the TAC from all three fisheries (Alaska, British Columbia and Pacific Coast) to get a single TAC number which represents the total annual potential supply of sablefish. Catch limits are set separately in the three fisheries. In the US fisheries, the sablefish season follows a calendar year. In Canada, the commercial sablefish fishery license year has changed from a calendar year to a season which extends from Aug. 1 - Jul. 31. The new system began in Aug. 2000, and so since then, the beginning and end dates of the British Columbia TAC guidelines do not coincide with those in the U.S. Rather than arbitrarily dividing the British Columbia TAC to coincide with a calendar year, we simply count the B.C. TAC in the year in which it is initiated. For example, the 2001/2002 TAC is counted as TAC in 2001. Since the B.C. fishery is relatively small compared with the US fishery (about 10% of total catch), the amalgam of two time periods for TAC data is not expected to significantly affect the estimated market demand models.

[1] http://swr.ucsd.edu/fmd/sunee/imports

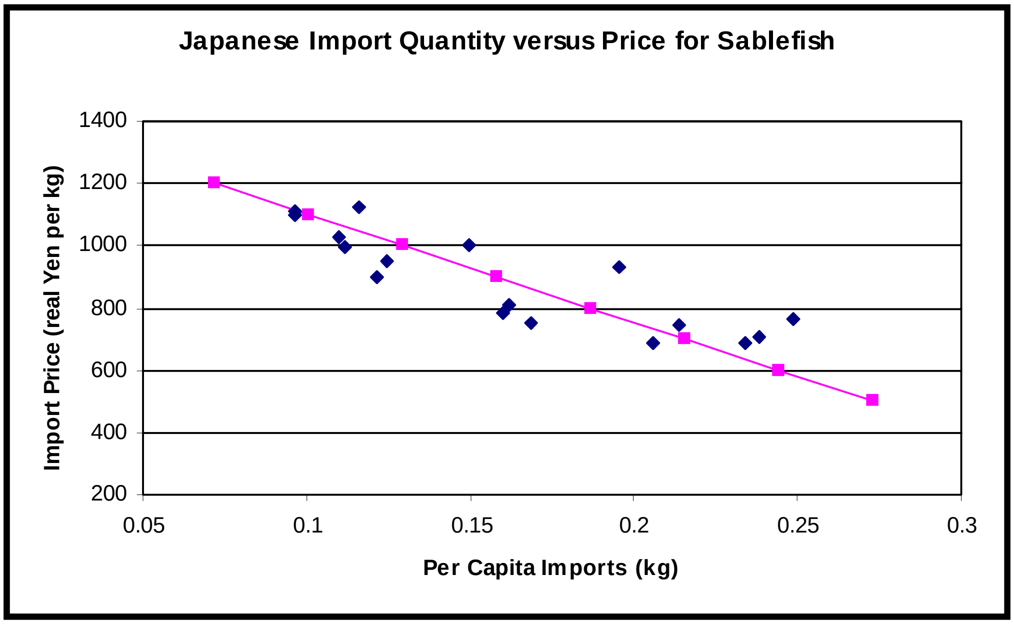

Figure 2. Japanese Sablefish market data, 1987 – 2003.

Sablefish Substitutes: Sockeye and Mero

Consumer preferences with respect to sablefish have changed over time. Jacobson (1982) originally determined that sablefish was a substitute for chum salmon, largely for use in winter stews. This is also the substitute used by Hastie (1989) in his analysis. However, sablefish ultimately became competitive with sockeye salmon in the "sliced fish" market (BANR, 1991). And as the price of sablefish rose through the 1980's, mero[2] was introduced as a cheaper alternative. Mero is now an important substitute for sablefish, and sliced fish processors will switch to mero production when sablefish is not available (BANR, 1997).

Data on imported sockeye salmon are of the same basic quality as sablefish data. We focused on imported frozen Pacific Sockeye. Although a single time series on Pacific Sockeye price was not available, we were able to build a time series from occasional reports found in Bill Atkinson's News Report, supplemented with import data posted on the NMFS Southwest Region's "Japanese Market News" site.

The data are less satisfactory for mero. Mero has only been counted separately in Japanese import statistics since 1996. We searched through Bill Atkinson's News Report from 1987 through 1995 and found some wholesale spot prices as far back as 1991. Nothing is available prior to that. There were no other sources for these data available, and the next step would be to find a Japanese translator who could search Japanese publications. Because we could not find a valid time series for this species, it was not included in the statistical analysis.

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[2] The name "mero" may actually describe more than one species of fish. Both the Patagonian Toothfish (*Dissostichus eleginoides*)and Chilean grouper (*Acanthistius brasiliensis*) are called "mero" in Japan. The common name Chilean Sea Bass may also apply to both species.

Price Indices and Demographic Data

Because the analysis includes markets in three different countries, it was necessary to convert prices using a "real exchange rate". The real exchange rate accounts for nominal differences in the units of national currency, as well as for differential rates of general price inflation between countries. Economic theory suggests that it is the "real" price of goods that matters to economic agents; that is, a price is perceived to increase (or decrease) only if it changes *relative* to the general price level observed for other goods in the same general category. It is common to use the consumer price index to correct for overall price changes in consumer goods, and so we converted nominal sablefish prices in Japan to real prices using the Japanese consumer price index. On the other hand, ex-vessel prices in North America are converted to real prices using producer price indices for Canada and the United States, since the relevant prices for comparison on the supply side are sellers' prices. We downloaded the necessary price indices from the sources indicated in Table A4, and converted each index so that the base year would be the year 2000 for all currencies.

The quantity of sablefish demanded in Japan can change because the price changes, or it may also change if the size of the market changes. Even if prices remain the same but the population grows, one would expect the quantity demanded to increase. Thus it is necessary to account for the size of the Japanese population. This is best achieved by analyzing per capita demand rather than aggregate demand. We therefore obtained data on the Japanese population and used it to calculate per capita imports of sablefish.

In the same way that an increase in the size of the market might increase the quantity of sablefish consumed even if the price stays the same, so can income changes affect demand. To account for income effects, we obtained data on Japanese Gross Domestic Expenditure (an equivalent measure to Gross Domestic Product in the United States) and converted it to real per capita income using the Japanese consumer price index and the population time series.

B. Predicting Price Changes – Methods

In this section, we describe briefly the quantitative and statistical model developed to forecast the effects of supply increase on sablefish prices. Only the main characteristics of the economic model are noted here. The details of the model are explained in the Technical Appendix to this report.

We began with the assumption that the overall level for the price of sablefish is determined in the Japanese market, and that ex-vessel prices depend upon Japanese prices. Prices in Japan are determined by (a) imported supply and (b) consumer demand. This concept of the market structure led to development of a model with 5 simultaneous equations. The first two equations represent the supply and demand curves for sablefish in Japan, and the remaining three equations quantify the relationship between market price in Japan and ex-vessel sablefish prices in Alaska, British Columbia, and the Pacific Coast.

To deal with currency exchange rate variability between the US dollar, the Canadian dollar, and the Japanese yen, each price in the model is expressed in terms of the currency used in the market being modeled. Further, varying in-country currency values due to inflation is recognized by deflating each nominal price in each currency unit by the corresponding national consumer or producer price index. For example, the demand equation for Japan measured prices in real yen. Ex-vessel prices are expressed in real US dollars for Alaska and the Pacific Coast, and in real Canadian dollars for British Columbia.

We estimated the equations simultaneously in order to incorporate feedback effects between supply and demand, and also to better account for effects in the market that can't be measured, but which might affect both Japanese and North American markets at the same time. Once an overall relationship between price and quantity was established for the base period (1987 - 2003), then the model was used to predict how changes in supply would ultimately affect ex-vessel prices. This general approach has been used to answer similar questions regarding supply in the Alaska Snow Crab and Walleye Pollock fisheries (Greenberg *et al.* 1995 and Herrmann *et al.* 1996, respectively), as well as for predicting the price of farmed Atlantic Salmon in the early 1990's (Lin *et al.* 1989).

Our baseline analysis focuses on the recent period of 1987 to 2003, because Japanese import data are not available prior to that, and because Americanization of the fishery was completed just a short time before that (1985). The model is used to predict the effects of 7 levels of increased sablefish supply between 5 and 100 thousand metric tons.

In our price estimates aquaculture fish are treated as equivalent, from the consumer's point of view, to fish supplied from the North American fishery. Hence, an increase in supply from fish farms is equivalent to an increase in annual total allowable catch (TAC) for North American fisheries. If, on the other hand, the cultured sablefish differ significantly from wild-caught, due to size or flesh quality for example, then the effect of increased supply from aquaculture on demand for wild-caught fish would be attenuated and prices would fall somewhat less than our estimates indicate. Currently, no information exists regarding Japanese perceptions of the relative quality of aquaculture sablefish. To put this into perspective, we note that other analysts (Asche, *et al.* 2001) have found that aquacultured salmon and wild-caught salmon are very close substitutes. But it is possible that, over time, consumers will learn to expect different qualities from wild-caught and farmed fish, leading to distinctly different sub-markets for the two product types.

A Note about the Japanese Economy

The effect of supply on prices depends in part upon the economic context in which the supply increase takes place; that is, it depends upon foreign exchange rates, Japanese income, *etc.* During the 1990's, which comprises most of the study period, Japan's economy was in turmoil. There were two major recessions in Japan during this time period, both of which may have impacted consumer prices. In fact, sablefish prices are seen to be particularly volatile from 1991 to 1993, and from 1997 to 1999, coincident with these two recessions.

For this reason, we present two models below. The first model estimates demand in Japan using a standard demand specification which includes the price of the substitute (sockeye salmon in this case) and per capita income. The second model attempts to capture the effects of the macroeconomic environment in Japan. This model includes the nominal yen/dollar exchange rate and income volatility (measured as the deviation from the long-term trend). Japan relies heavily upon imports, and so changes in the strength of the yen can have significant effects upon consumer prices for imports such as sablefish. Similarly, brief periods of unexpected economic growth or contraction may cause unusual price effects.

Background Economic Variables

As noted above, the prevailing economic conditions outside of the sablefish market can affect the outcome of a supply increase within the sablefish market. The two models presented below use slightly different approaches for explaining the observed variation in sablefish prices over the last decade and a half, but for both models, it is necessary to assume a particular set of economic conditions as the background for the hypothesized supply increase. In traditional econometric jargon, this means assuming values for the exogenous variables (the variables we are not trying to predict). We chose to use the average conditions over the years 2001-2003 (the most recent three years of our sample) as the background. Thus, the baseline TAC is the average for 2001-2003 (= 27,964 metric tons). The background values for exchange rates, the Japanese population, income, *etc.*, are all the averages for 2001-2003. Thus, we are not attempting to forecast the future price of sablefish. Instead, we are attempting to predict what the price would be if supply increased, *all else remaining equal.*

C. Price Estimates from Model 1

As expected, the standard market model for sablefish, labeled as Model 1, yields a downward sloping relationship between overall quantity of fish supplied to the Japanese market and the price prevailing in that market (see Figure 3 below). This represents the national market demand for sablefish in Japan. The open circles in Figure 3 represent the annual price-quantity observations for 1987 – 2003, while the straight line represents the estimated market demand curve. Generally, the model "fits" the data reasonably well, and we can predict broad changes in market price in Japan due to large changes in total sablefish quantity supplied to Japan.

There are two additional observations to be made from Figure 3. First, the estimated demand curve is simply that – an estimate. The scatter of points about the curve indicates the degree to which actual annual price response to quantity variation can be accurately predicted by this model. As shown, the price predicted by the model (the straight line) can be as much as 20-25% above or below the actual price recorded. The variability of price about the prediction is at least partly explained by variation in other factors included in the demand model – trends in Japanese consumer population, income per capita, and price of substitute fish products (e.g. sockeye salmon). We have not attempted to forecast future changes in those other independent variables. Hence, we can claim only to predict gross trends in price due to substantial changes in quantity. Second, substantial increases in sablefish supply push our forecasts well beyond the range of observed historical quantities. For example, imports of sablefish to Japan in 2002 was roughly 20,000 metric tons. An increase in supply of +50,000 mt, bringing the total imports to Japan up to 70,000 metric tons, would take us well beyond the largest supply actually observed in the data (Figure 3). A price prediction tends to deteriorate as we predict beyond the range of observed information, and so our estimates for increase of 50,000 mt and beyond are unavoidably speculative. Nevertheless, we feel that the model estimated here provides a reasonable and useful estimate of the price response to supply increase in Japan.

The forecasted price effects of supply increase in Japan, shown in Figure 3, translate back to ex-vessel prices in North America. Our 5-equation market model estimates linear equations that link Japanese wholesale price to observed ex-vessel prices in the Gulf of Alaska, British Columbia and the US Pacific coast fisheries. The effects of hypothetical supply increases on ex-vessel prices are listed in Table 4. Under the market conditions observed, an increase of 100,000 metric tons, whether from aquaculture or a resurgence of the ocean fish stock, would drive the prices down to near zero.

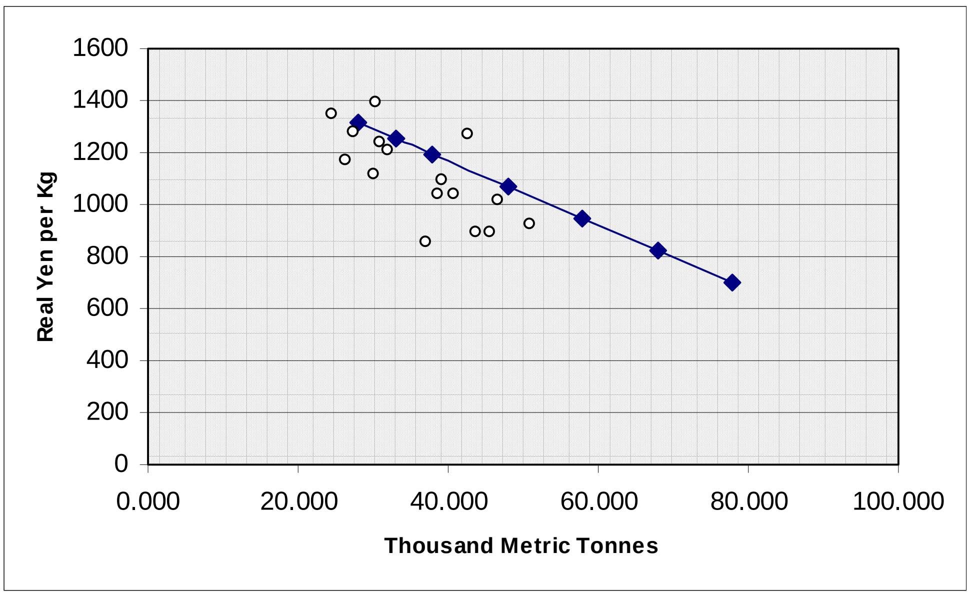

Figure 3. Projected Sablefish Demand in Tokyo - Model 1. (Price vs Total Market Quantity)

Table 4. Effect of Changes in Tokyo Price on Ex-vessel Prices (Model 1). Prices are estimates for fixed gear fisheries (lines/pots), measured in **real dollars per pound round weight**. British Columbia prices are in Canadian dollars.

Additional Supply (metric tons)	Total Supply (metric tons)	Estimated Ex-vessel Prices per Pound round-weight						% Change in Price
		Alaska		Pacific Coast		British Columbia		
		Price	Change	Price	Change	Price	Change	
0	27,964	$ 3.09		$ 1.58		$ 3.75		
+ 5,000	32,964	$ 2.94	-0.15	$ 1.50	-0.08	$ 3.56	-0.19	**-5 %**
+ 10,000	37,964	$ 2.80	-0.29	$ 1.53	-0.15	$ 3.39	-0.36	**-10 %**
+ 20,000	47,964	$ 2.51	-0.58	$ 1.28	-0.30	$ 3.04	-0.71	**-19 %**
+ 30,000	57,964	$ 2.22	-0.87	$ 1.13	-0.45	$ 2.69	-1.06	**-28 %**
+ 40,000	67,964	$ 1.93	-1.16	$ 0.99	-0.59	$ 2.34	-1.41	**-37 %**
+ 50,000	77,964	$ 1.64	-1.45	$ 0.84	-0.74	$ 1.99	-1.76	**-47 %**
+ 100,000	127,964	$ 0.15	-2.94	$ 0.07	-1.51	$ 0.17	-3.57	**-95%**
Actual Starting Prices		**$ 3.20**		**$ 1.66**		**$ 3.69**		

D. Price Estimates from Model 2

As noted above, Model 2 incorporates broad economic indicators for the Japanese economy (dollar/yen exchange rate and GNP instability) whereas Model 1 is limited to direct fish market factors (TAC, income per capita and per capita sablefish supply in Japan, sablefish price, and sockeye salmon price). Aside from that difference, Model 2 is analogous to Model 1: it is a five-equation, linear model of supply-demand in the Japanese market, augmented by three equations predicting the effect of Japanese market price on North American ex-vessel prices. As shown in Figure 4 below, Model 2 also provides forecasts of price changes due to increasing supply of sablefish, and the model is similar to Model 1 in the level of precision in the forecasts.

The main difference between the two models is that Model 2 predicts a more severe price effect of supply increases. A comparison of price forecasts in Tables 4 and 5 reveals this difference. For example, for a 50,000 metric ton increase in supply, Model 1 predicts an Alaska ex-vessel price drop of $1.45/lb whereas Model 2 predicts a drop of $1.93/lb. A supply increase of 100,000 metric tons would force the prices down to zero or less. While these latter estimates go beyond the range in which the model can confidently estimate price effects, they illustrate the limits of the Japanese market and the importance of further market development and expansion as an adjunct to any significant growth in aquaculture sablefish.

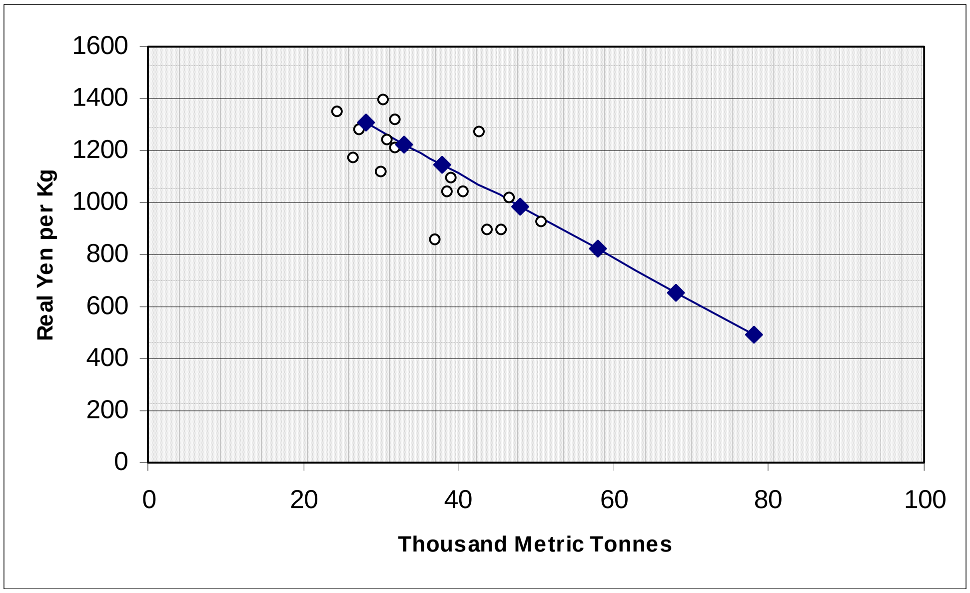

Figure 4. Projected Sablefish Demand in Tokyo - Model 2. (Price vs Total Market Quantity)

Table 5. Effect of Changes in Tokyo Price on Ex-vessel Prices (Model 2). Prices are estimates for fixed gear fisheries (lines/pots), measured in **real dollars per pound round weight**. British Columbia prices are in Canadian dollars.

Additional Supply (metric tons)	Total Supply (metric tons)	Estimated Ex-vessel Prices per Pound round-weight						% Change in Price
		Alaska		Pacific Coast		British Columbia		
		Price	Change	Price	Change	Price	Change	
0	27,964	$ 3.08		$ 1.57		$ 3.73		
+ 5,000	32,964	$ 2.88	-0.20	$ 1.47	-0.10	$ 3.49	-0.24	**-6 %**
+ 10,000	37,964	$ 2.70	-0.38	$ 1.38	-0.19	$ 3.27	-0.46	**-12 %**
+ 20,000	47,964	$ 2.31	-0.77	$ 1.18	-0.39	$ 2.80	-0.93	**-25 %**
+ 30,000	57,964	$ 1.93	-1.15	$ 0.99	-0.58	$ 2.34	-1.39	**-37 %**
+ 40,000	67,964	$ 1.54	-1.54	$ 0.79	-0.78	$ 1.87	-1.86	**-50 %**
+ 50,000	77,964	$ 1.15	-1.93	$ 0.59	-0.98	$ 1.40	-2.33	**-62 %**
+ 100,000	127,964	$ 0.00		$ 0.00		$ 0.00		**-100 %**
Actual Starting Prices		**$ 3.20**		**$ 1.66**		**$ 3.69**		

E. Other Factors Affecting Sablefish Market

The market models developed in the previous sections are limited to considering the effects of increased sablefish supply entering the Japanese market. Limiting the analysis to the existing market facilitates our use of quantitative modeling to estimate the price response on North American ex-vessel sablefish prices. On the other hand, this approach to market price analysis does not consider some potentially important factors which are less easily incorporated into a quantitative model. One such factor is expansion of sablefish consumption in North America (or even Europe) in response to increasing populations, seafood demand, and declining availability of some competing seafood products.

One example of such a product is the Patagonian toothfish, widely distributed under the name “Chilean seabass”. It is a very popular, high quality product from the deep, cold waters of high latitude southern hemisphere. Toothfish apparently occurs in many “stocks” which have been sequentially exploited by longline fishing vessels from South America and elsewhere. Official records of harvest are summarized in Figure 5 below, but many people believe that the harvest rates are far in excess of the official recorded harvests, and that the populations of toothfish are being severely over-fished. If this fear proves to be the case, the downward trend in supply of toothfish will continue.

The US market has responded favorably to the introduction of toothfish during the 1990s. Recent official US import statistics and reported import value per pound are displayed in Figure 6 below. While the color, oil content, and flesh quality of toothfish differs from that of sablefish, some seafood experts find the sablefish to be similar enough to the toothfish that there may be some increase in sablefish sales as a substitute for toothfish and other white-fleshed fish.

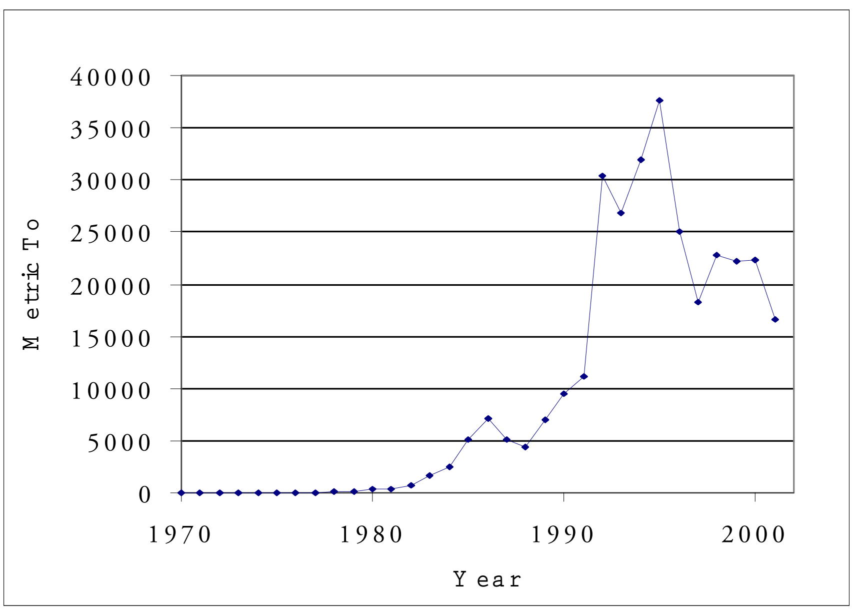

Figure 5. World Harvest of Patagonian toothfish. Source: FAO FishStat+ database.

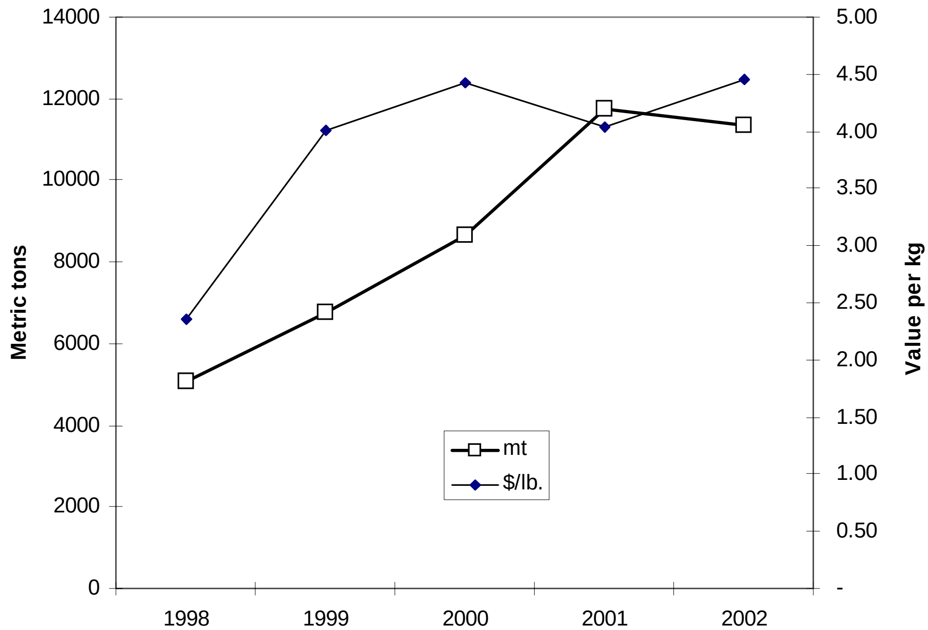

Figure 6. US imports and value/lb for Chilean sea bass (Patagonian toothfish). Source: NOAA Fisheries Statistics.

Import prices for toothfish reported for 2000 through 2002 equal or exceed the recent ex-vessel prices of sablefish in Alaska. This suggests that sablefish could compete in that high value restaurant market based upon price. The future prospects for toothfish supply are bleak, as enforcement of conservation measures in the Antarctic ocean appear inadequate. If the toothfish harvest continues to decline, and the market price continues to rise, it seems likely that sablefish can be marketed as a substitute, frozen product. A rough guess would be that the US market might absorb 5 to 10 thousand metric tons of additional sablefish, and that the world market might absorb twice that amount. This would occur over several years, and it is contingent upon the continuing decline in toothfish and upon the acceptability of sablefish to seafood consumers.

For illustration, if sablefish is sold as a substitute for toothfish or other white-fleshed fish, this additional market outlet for sablefish will moderate the price-depressing effects of increased sablefish supply that were considered in Sections C and D above. But this will not stop or reverse the price declines caused by increasing supply from aquaculture. For example, using our Model 1 to estimate price effects, if total supply of sablefish increases by 20,000 mt, and 10,000 mt of sablefish is sold in the expanded north American market, the effect on Alaska ex-vessel price of sablefish would be approximately the same as the predicted effect of a 10,000 mt increase in supply to the Japanese market. That is, with the expansion of American market demand, a 20,000 mt supply increase would depress ex-vessel price from $3.09/lb to $2.80/lb rather than from $3.09 to $2.51.

IV. TECHNOLOGICAL DEVELOPMENT, REARING COSTS AND IMPACT ON THE SABLEFISH FISHING INDUSTRY

In this chapter we address the last two question posed in the research proposal.

- Is the development of sablefish farming in British Columbia likely to occur in the near future, and, if so, what is likely to be the average cost of production (or minimum viable price)? and
- Will the sablefish farming technology be readily transferable to less developed nations, and which multi-national corporations are likely to be involved in the spread of sablefish farming?

Because sablefish farms operating at commercial production levels are a relatively new innovation, a thorough assessment of costs and economic performance is not available. Instead of analyzing data on existing sablefish farming operations, we approach these questions through examination of scientific research papers and aquaculture trade reports, inference from the reported experience in the salmon farming sector, and expert judgments and speculations obtained through interviews and discussions.

A. The State of Science and Technology in Sablefish Culture

Research on sablefish culture dates back to the mid-1960's. Early efforts involved capturing wild juveniles and feeding them in captivity to determine the potential for commercial sablefish farming (Kennedy 1972). Because juveniles up to two years of age inhabit inshore environments, they are more accessible than the marketable adults which dwell in very deep water. Thus, it was natural to speculate that it could be profitable to capture fish at this earlier stage and culture them to a marketable size. Juveniles (weighing approximately 300g) were captured in trawl nets or with baited hooks, and then raised in tanks or sea cages at the Pacific Biological Station in Nanaimo, employing a variety of growth conditions and diets. Overall, the early research showed that juvenile sablefish could be reared to market size (4kg) in less than two years, that they were not overly-sensitive to crowding, and that the cultured smoked product compared favorably with trawl-caught smoked sablefish (Kennedy 1972). Similar work was performed in the US and the National Marine Fisheries Service's facility at Manchester Washington (Gores and Prentice 1984).

Despite these encouraging results, the practice of farming wild juveniles did not develop into an industry. It was determined that hatchery production of juveniles would be necessary before the industry could achieve commercial success, since the wild population was already fully exploited and there were (unspecified) problems associated with transporting juveniles (Clarke 1994). However, hatching eggs and rearing larvae of marine fish species, sablefish included, is much more difficult than it is for salmonids. Hatchery production of juveniles is considered the limiting factor in the culture of most cold water marine species (Tilseth 1990). The first problem is that most marine fish produce very small and fragile pelagic eggs which are prone to mechanical damage in culture. Incubation tanks must provide adequate flow without imposing physical stress upon the eggs. Second, cold water marine species have relatively longer incubation and yolk sac stages than do temperate or tropical fish, and these early stages can be particularly vulnerable to bacterial infections (Tilseth 1990). Third, and most problematic, is the early feeding regime. While salmonids will accept a small commercial pellet immediately upon yolk sac absorption, cold water marine species require a live diet of rotifers and/or *Artemia* before they can be "weaned" to a commercial pellet (Clarke *et al.* 1999, Tilseth 1990).

To culture sablefish on a commercial scale, methods have been, or are being, developed with varying levels of success for each of the following stages:

a) inducing spawning in adults,
b) incubating eggs,
c) rearing larvae, and
d) growing out juveniles.

Spawning

Mid-February is the natural spawning time for sablefish. But an annual spawn is too restrictive for commercial scale farming, and it has constrained the availability of specimens for research on incubation and larval rearing techniques. Kroeger *et al.* (2002 Unpublished) controlled photoperiod to induce egg development 4 months before and 4 months after natural spawn timing. Results have been mixed, and chemical hormone treatments are generally necessary to bring about final maturation and hydration of the eggs. Egg quality influences fertization success (Clarke *et al*. 2002 Unpublished), and the production of high quality eggs through induced maturation remains somewhat unreliable. However, a single female spawner can produce 450,000 eggs, so that even a low success rate and/or small broodstock may be sufficient for large-scale production. To date, researchers have relied upon wild-caught broodstock for egg and milt production, and only one researcher at a commercial farm has apparently succeeded in "closing the life cycle" to produce domesticated breeders (Drouin and Warren 2001).

Incubation and Larval Rearing

The production of juvenile sablefish from eggs was first achieved in 1998 (Clarke *et al.* 1999). Experiments with rather complex incubation systems (Alderdice *et al.* 1988) eventually led to success with simple upwelling incubators. The following description of the incubation and rearing process is paraphrased from Clarke *et al.* (1999). Eggs hatch after approximately 2 weeks incubation at 6˚C, and the hatched larvae are held in the same incubators for an additional 3 weeks during yolk-sac resorption. At 5 weeks from the onset of incubation, larval fish are transferred to feeding tanks and are ready for first feeding. Rotifers are introduced to the diet first, and three weeks later, the regime is switched to *Artemia* (brine shrimp). A commercial dry diet is not introduced until 5 weeks after first feeding, and the larvae are "weaned" from live food 2-3 weeks later. At this point (12-13 weeks after onset of incubation) the larvae are about 3cm in length and weigh approximately 1 g. Growth is rapid beyond this time.

Mortality may be high during larval rearing, and in particular during two developmental transitions. High mortality is first observed at the transition between yolk sac resorption and exogenous feeding, and then again during a stage called "notochord flexion" when the caudal fin of the fish develops. Clarke *et al.* obtained survival rates of 5-10% between the first feeding at 5 weeks and the time of weaning to commercial diet about 8 weeks later. Temperature control appears to be important at this stage, and slowly raising the temperature in feeding tanks to 10˚C from the 6˚C incubation temperature improved larval feeding (Clarke *et al.* 1999). In addition, the nutritional composition of the live food is important, and careful attention to the culture of the rotifers, in particular, is required (Clarke 1994).

A successful sablefish hatchery will need equipment and operational controls for careful water temperature control. And because a live diet is required for early feeding, the hatchery will also require incubation facilities for rotifers, the microalgae fed to the rotifers, and perhaps also for *Artemia*. It is unknown at this point whether (or at what stage) larvae can be shipped successfully from a hatchery to a remote grow-out site.

Juvenile Grow Out

The culture of juvenile sablefish into adults is well worked out. Although an optimal diet is the subject of ongoing research (Balfry *et al.* 2003 Unpublished; Shearer 2003 Unpublished), success was obtained early on with the same diet fed to farmed salmon (Gores and Prentice 1984). Juveniles can be transferred to pens at 5g body weight, and have reportedly been grown to a weight of 1 kg within 6 months on a private farm in British Columbia (Drouin and Warren 2001). Sablefish can be raised in net pens like those used for salmon culture, and growth is similar or more rapid than that achieved with salmon. Culture may also be possible within the more controlled environment of floating bag systems (Clarke 2001), though the results with wild fish were mixed and the method has not yet been tried using domestic fish.

With current technology, it appears that it will take two to three years of culture time to raise each crop of market-ready sablefish. Minkoff and Clarke (2003) claim that 5-20g juveniles can be grown to 7-8 lb fish over a period of 2 years.

B. Costs of Rearing Sablefish

In the long run, the costs of rearing and delivering farmed sablefish to Japan (and to other markets) will determine the market price, and based upon the demand curves estimated above, the price will determine the extent to which sablefish consumption increases. Fundamentally, the average cost of farmed fish production, plus cost of packaging and transportation, will become the major determinant of price. Hence, understanding and projecting the likely costs of operating sablefish farms is important to an assessment of how farming will affect the existing sablefish fishing industry.

The cost considerations are logically divided into three stanzas: (1) production of juveniles ready for rearing in net pens, (2) rearing of juveniles in net pens to harvestable size (2-8 lb. fish), and (3) the cost of harvesting, processing and transporting. As is clear from the discussion above, rearing sablefish from egg to juveniles of appropriate size/age for introduction to net pens is the major challenge in sablefish culture, while raising to harvestable size in net-pens appears to be an extension of existing salmon net pen culture practice. Sablefish farmers will need to experiment and perfect feeding regimes and disease control methods for sablefish. But the real technological challenge lies in maintaining a brood stock of mature fish, adjusting temperature and light conditions to induce spawning over an extended length of time, handling the eggs, and rearing larvae to juveniles. These challenges will need to be overcome in the hatchery stage, rather than in the net-pen rearing stage.

There are at least two potential commercial sablefish hatcheries of which we are aware: Island Scallop in Qualicum Beach, British Columbia and Sablefin Hatcheries Ltd. on Saltspring Island, British Columbia. Island Scallop is reported to be selling 5-gram juvenile sablefish at C$4 a piece (equals $2.85 US in 2003), and is expected to produce about 300 thousand juveniles per year. Sablefin Hatcheries has built capacity to deliver 2 million juveniles per year, and has announced plans to expand to a capacity of 10 million juveniles. Experience in the Atlantic salmon industry suggests that as hatcheries overcome technical and commercial problems of operation, the cost per smolt (or juvenile, in the case of sablefish) will trend downward. According to one industry expert, the price per smolt delivered to farm operations hovered around $ 4 (US) during the 1980s and into the 1990s. But, as more hatcheries scaled up operations, the price declined to around $1.25. The reported price for sablefish juveniles seems to be starting out at a lower price ($2.85), and we can expect that the price will decline eventually. However, it probably would go no lower than the current low price of salmon smolts, since the complexity of rearing sablefish larvae will always be greater than that of raising salmon smolts.

Since we have found no reliable cost accounts for sablefish rearing operations, we begin our production cost analysis by considering the typical cost breakdown reported for rearing Atlantic salmon to harvestable size (See Table 6). Then we conservatively assume that rearing sablefish juveniles to harvestable size will cost the same as Atlantic salmon, per unit weight of final product. This means that the feed conversion ratios, mortality incurred during net-pen rearing, and growth rates are about the same for sablefish and salmon. Whether these assumptions prove correct will be revealed as more experience is gained in sablefish farming. Table 6 displays a variety of information about Atlantic salmon farms in Chile, Norway, and British Columbia. All the dollar figures have been converted to US $ to ease comparison. The British Columbia salmon farm data is a bit out of date, having come from a report published in 1995, based upon data for 1994. The last column of Table 6 represents our best guess regarding current salmon farming costs. It was constructed from the information in the previous columns as described in the Table footnotes. Basically, we assume that British Columbia farms encounter overhead and packaging expenses equivalent to those elsewhere, and that the recent decline in farming costs experienced in Norway would be reflected in British Columbia’s costs as well.

Next, we construct the cost display in Table 7 for sablefish farming which incorporates the reported cost of sablefish juveniles from Island Scallop, hypothesizes a 75% survival to harvestable size, includes rearing costs (net of smolt costs) per unit weight of $1.62 per kg, assumes a harvestable size of 3 kg (6.61 lbs), a product yield of 68% for J-cut fish, and processing/packaging costs of $0.27/kg to get a total ex-farm average cost of $4.51/kg or $2.05/lb.

Finally, we recognize that the cost of juveniles is likely to decline eventually as hatchery operations are streamlined and more companies enter the business. Also, the survival from juvenile to harvestable size is likely to increase to the range of 90% to 95% as sablefish operations gain experience and implement specific procedures to optimize feeding and fish health measures. These two variables – juvenile fish cost and survival – have an impact on the projected average costs per unit weight of sablefish product.

The “sensitivity analysis” displayed in Table 8 demonstrates that hatchery prices and survival rates for juvenile fish, over the projected range of $3.50 to $1.25 per juvenile, can push the average cost per pound of final product up to as high as $2.24 or down as low as $1.48. The price of juveniles appears to have the more significant influence (accounting for between a $0.67 and a $0.51 difference in cost/pound), while the survival rate has a more moderate effect (between $0.25 and $0.09 per pound). Given the likely trend in both survival and hatchery costs over time, our best guess is that the cost per pound of farmed sablefish could settle in the neighborhood of $1.67/lb. This assumes that hatchery costs and juvenile price drops to $2.00/lb (lower than current price, but still well above the price of salmon smolts), and that survival rates improve to 95%, which is slightly lower than most salmon farms currently experience.

C. Likelihood that Sablefish Farming Technology will be Transferred Overseas

Based upon experience in the development and spread of aquaculture technologies for salmon, shrimp, halibut, cod and other species, one would have to conclude that sablefish farming technology will be taken overseas and implemented wherever it proves profitable. Three factors that could enhance or delay the spread of this technology are: (1) the availability of the developing technological knowledge to commercial interests who might operate overseas, (2) presence of appropriate physical conditions, such as cold water temperatures for rearing sablefish, and (3) presence of supportive business and legal climate for fish farming. We briefly discuss each of these in turn.

(1) The technology seems relatively easily accessible to interested commercial operators. Most of the information that we reviewed to assess the current state of sablefish rearing technology was easily available from published sources, and augmented by conservations with authors of those publications. There may still be specific skills and techniques learned, on-the-job by commercial hatchery operators, and that information may be less easily accessed. But even here, the scientists and technicians working in marine finfish culture are somewhat mobile amongst firms and nations. So, our assessment is that the technology could be taken to any nation seriously interested in establishing a sablefish farming operation. Because they have broad experience in rearing salmon species in net-pens, companies and nations with established salmon farming are most likely to have the requisite technical skills to take up sablefish farming. These include, obviously, Canada (east coast and west coast), Chile, Iceland, Ireland, New Zealand, Norway, and Scotland.

(2) Physical conditions for sablefish culture include relatively well protected inland waters with temperatures of 12°C or less for rearing juveniles to harvestable size and 6°C water for incubating eggs and rearing early larvae. The colder temperatures apparently needed for the early life stages may put some constraints on where sablefish may be profitably reared.

Locations reasonably certain to meet these requirements are Canada, southern Chile, Iceland, Norway, and the Russian far east. Areas with ambient water temperatures in excess of 6°C may still operate hatcheries for sablefish, at somewhat increased expense, by chilling seawater in a closed, re-circulating water system.

(3) All the nations mentioned so far, with the exception of Russia, have the legal and business climate necessary to attract capital from international aquaculture firms for start-up of sablefish culture as an adjunct to salmon farming.

Table 6. Information on Production Costs for Atlantic Salmon Farming.

	(1)	(2)	(3)	(4)	(5)
	Chilean[1]	Norway 1998	Norway in 2002	Brit Col. 1994	Brit. Col. est. 2002
Item	$/kg	$/kg	$/kg	$/kg	
Smolts	$0.24	$0.37	$0.28	$0.64	$0.47
Feed	$0.91	$1.26	$0.90	$1.20	
Additives	$0.30			$0.06	
Labor	$0.08	$0.22	$0.18	$0.32	
Insurance	$0.03	$0.03	$0.03	$0.04	
Maintenance	$0.05	$0.00	$0.00	$0.00	
Finance/Interest	$0.07	$0.10	$0.06	$0.00	
Other	$0.03	$0.36	$0.33	$0.40	
Total direct Production Cost	$1.70	$2.35	$1.77	$2.66	$ 1.995
Operation/Overhead	$0.12				
Depreciation	$0.09	$0.08	$0.09		
Transportation of harvest to plant	$0.07	$0.03			
Farm cost (round weight)	$1.99	$2.46	$1.85		$ 2.09
Head-on yield 91%	$2.18	$2.70	$2.03		$ 2.30
Processing	$0.33	$0.00			
Packaging	$0.20	$0.31	$0.27		$ 0.27
Processed Costs (whole, dressed, head-on	$2.71	$3.01	$2.31		$ 2.57

Sources:
Col.s (1) and (2): Bjorndal and Aarland (1998).
Col. (3) : Bjorndal (2002)
Col. (4): Forster (1995)
Col. (5): Calculated from the previous columns as follows: (a) smolt cost and other direct production costs from Col (4) by % drop in Norway's costs from 1998 to 2002. (b) indirect costs in proportion to indirect to direct in Norway are added to direct production cost to get estimated Farm cost; (c) head-on yield in B.C. assumed to be the same as elsewhere, and (d) packaging costs equal to those reported for Norway are added to British Columbia salmon farm costs.

Table 7. Projected Costs of Raising Sablefish from juvenile to 3 kg (6.6 lb.) adult. Assumes price of juvenile from hatchery is $2.85, survival from juvenile to harvest is 75%, and cost of rearing per kg harvesting is the same as for Atlantic salmon.

	Cost/kg	**Cost/lb.**
Juveniles	$1.27	$0.57
Other Direct Farm Costs	$1.62	$0.73
Farm Cost Round Wt.	**$2.88**	**$1.31**
J-cut yield (80% yield)	$4.24	$1.92
Packaging & Processing	$0.27	$0.12
Processed Cost	**$4.51**	**$2.05**

Table 8. Sensitivity Analysis of Farmed Sablefish Product Costs. Uses the figures from Table 7, but with price of hatchery juveniles ranging from $3.50 to $1.25, and survival rate from juvenile to harvest ranging from 50% to 99%.

	Cost per Juvenile			
Survival	$3.50	$2.85	$2.00	$1.25
0.50	$2.76	$2.47	$2.09	$1.76
0.75	$2.24	$2.05	$1.80	$1.57
0.85	$2.12	$1.95	$1.73	$1.53
0.9	$2.07	**$1.91**	**$1.70**	$1.51
0.95	$2.02	$1.87	$1.67	$1.50
0.99	$1.99	$1.84	$1.65	$1.48

D. Likely Extent of Development in Sablefish Farming

Given the calculations, interpretations, and conclusions listed above, we conjecture that it is likely that sablefish farming will grow slowly over the next 5 years. The current plans for hatchery production in British Columbia would provide sufficient juvenile fish to produce roughly 6,555 mt of sablefish round weight or 4,457 mt product weight (with 95% survival, 3 kg fish at harvest, and 68% product yield). This could occur over the next 4 years or so as the planned hatchery comes on line and existing salmon farmers diversify into sablefish culture. Sablefish farms will be a profitable venture if the product is sold in Japan at prices consistent with our models of the Japanese market demand, and given our estimated sablefish production costs. We can conclude this after comparing the cost per pound of farmed sablefish (roughly $1.31/lb. round weight) with the projected ex-vessel price of sablefish in Canada and Alaska after the supply increases by 4,457 mt (roughly $2.95 in Alaska and $3.58 in British Columbia). Since the expected costs of farmed fish per pound of product is well below the projected ex-vessel price per pound round weight, the farmed fish could be very profitable. A possible stumbling block would be inadequate fish quality/color from the net pens. The Japanese market is sensitive to color and oil content (preferring white flesh and high oil content). We can't confirm that the farmed fish will have the high quality characteristics, but we also have no evidence to suggest otherwise.

If sablefish culture proves profitable, then additional hatcheries are likely to be established, possibly involving owners of existing salmon hatcheries that seek to diversify into marine fish. A more rapid expansion could follow a moderate growth in the next 4-5 year period, and salmon net pen operators will see an opportunity to diversify their businesses. Sablefish farming could expand out from British Columbia to other countries as mentioned above. The expansion of sablefish culture, like that of most competitive industries will continue until the price declines to the point that it just covers average costs of production. Given likely range of average costs per pound of product of $1.67 to $2.05, and using our two models of the Japanese market demand (Tables 2 and 3 above), we can calculate the likely extent of sablefish supply expansion through aquaculture development by determining what supply increase pushes the price down to the average cost level. Using the Alaska ex-vessel price projections as the basis, we find that, with Model 1 (Table 4) the price would fall to $2.05 when the farmed fish sector grows to produce 35,826 mt (augmenting recent ocean harvests of 27,964 mt); and the price would fall to the $1.67 level when supply increases by 47,931 mt. Using the Model 2 estimates (which suggests a more rapid price response), it would take an additional 27,105 mt supply to push the Alaska ex-vessel price down to $2.05 and a 37,105 mt supply increase to push price down to the $1.67/lb.. The general conclusion would be that an expanding sablefish farming industry, supplying solely the Japanese market, would reach market saturation at a production level between 27 thousand mt and 48 thousand mt. If the capture fishery also expands there would be less room for aquaculture fish in the Japanese market.

The projections made here assume that high quality sablefish continues to go predominantly to Japan. If restaurant markets in the US begin purchasing sablefish in significant numbers, possibly to substitute for other white fish (such as Chilean sea bass), then the room for aquaculture expansion in markets for high quality, high oil content fish, could be greater.

IV. CONCLUSIONS

We summarize our finding and conclusions regarding three principle issues: (1) the degree to which an expanding sablefish aquaculture industry is likely to impact the wholesale and ex-vessel market prices for sablefish, (2) the likely costs of sablefish farming and the likelihood that sablefish farm technology will spread from British Columbia to other marine finfish culturing nations, and (3) the magnitude of sablefish farming that is likely to develop, given the estimated demand for sablefish in the Japanese market.

The price forecasting models developed in this research project are based upon data from both Japanese markets (wholesale prices in Tokyo and reported imports, Japanese incomes and populations), and North American fisheries (harvests and ex-vessel prices and TACs), and currency exchange rates. The procedures follow recognized econometric modeling and statistical estimation approaches developed in the fishery economics literature. We have explored a wide range of statistical models (linear and non-linear with various numbers of equations) and have selected two specific forecasting models that represent the best available statistical estimates combined with model simplicity and intuitive features.

Generally, we estimate that the wholesale price in Japan will drop linearly as the overall quantity supplied increases. Our Model 1 forecasts that the ex-vessel price in Alaska will drop $0.029 per pound for each 1,000 metric ton increase in supply of sablefish; the ex-vessel price in British Columbia will drop $0.035 per pound for each 1,000 metric ton supply increase; and the Pacific coast ex-vessel price will drop $0.015 per pound for each 1,000 metric ton supply increase. Our Model 2, which incorporates effects of income volatility and exchange rates on the Japanese market, forecasts more severe price changes. For a 1,000 metric ton increase in overall sablefish supply, the Model 2 forecasts price reductions of $ 0.039, $0.047, and $0.020 per pound for Alaska, British Columbia, and Pacific coast fisheries respectively. The actual effects of prospective sablefish supply increases will likely fall in the range of estimates provided by these two models.

In using these price forecasts to plan for future fishery operations or management actions, two provisos should be kept in mind. First, we have not incorporated future changes in market structure or product quality in the forecasts. If Japan becomes less important to the sablefish market, due to increasing North American demand or the emergence of other Asian markets, our predictions will prove to be too dire. That is, expansion of markets for sablefish outside of the traditional Japanese market will attenuate the price effects of expanded sablefish supply (whether from growing TACs in the fisheries or from expansion of aquaculture production). Also, if production of sablefish in aquaculture operations is focused on smaller fish or niche markets which differ from the main Japanese markets, the effects on ex-vessel markets in the fisheries will be less than predicted by our models. In other words, our predictions assume that any increase in supply from the aquaculture sector would provide identical fish products and would compete directly with the existing fishery. To the extent that this proves to be untrue, our predictions of price effects will over-estimate the price reductions caused by aquaculture production of sablefish.

A second proviso is that we have not attempted to forecast the future trends in other factors affecting sablefish demand in Japan or elsewhere. The model estimates indicate that demand for sablefish is sensitive to consumer incomes and to the price of substitute fish products. If the economy of Japan experiences significant expansions or contractions relative to recent experience, the demand for sablefish there will grow or shrink more than we have estimated; and the Japanese wholesale prices will rise or fall relative to our price predictions. These changes will translate back to the ex-vessel prices in north America as indicated by the price linkage functions estimated in our models. Because we cannot forecast the future of the Japanese economy with any confidence, the price estimates provided by our research must be viewed as contingent on the continuation of recent level of economic prosperity in Japan.

Our attempts to project the likely costs of rearing sablefish focused on the costs of producing net-pen-ready juveniles and the costs of rearing fish in net-pens to a harvestable size of 3 kg. The cost of sablefish hatchery operations are expected to be higher than the cost of salmon hatcheries due to the more difficult and stringent requirements for incubating eggs and rearing larvae. Based upon a recent price quote, we expect the price of juveniles to start at $2.85 (US dollars) and to decline over time if sufficient demand develops to encourage additional commercial hatcheries to enter the business. Even with further development in sablefish hatchery technology and expertise, the cost of sablefish juveniles will probably remain above the cost of salmon smolts (roughly $1.25). Rearing the sablefish juveniles in net pens is expected to cost about as much per unit weight as the cost of rearing Atlantic salmon (roughly $0.73/lb). Given an 85% survival rate for juveniles, and a $2.85 price of juveniles, the final product cost per pound would be roughly $1.95 (Table 8). This estimate is highly dependent on a number of factors -- the assumed price of juveniles, survival to harvestable size, product yield, cost of rearing, processing, and packaging. Given a reasonable range of juvenile fish costs and of survival rates, the estimated costs per pound of final product ranges from $2.76 (50% survival and juvenile cost of $3.50) to $1.48 (99% survival and juvenile cost of $1.25). The most likely average cost level is centered between these extremes. Comparison to recent average ex-vessel prices in Alaska and British Columbia, suggests that sablefish culture, under the conditions listed here, would be profitable, even though the addition of farmed sablefish to existing market supplies will initially push prices down.

Given this expected profitability, and the wide availability of most technical information needed to gear up for sablefish culture, we would expect that sablefish culturing practice would spread to a few other countries which have appropriate water temperatures, pre-existing technical know-how, and favorable political and economic climates. These nations could include (besides Canada) Chile, Norway, Iceland, Scotland, and possibly New Zealand. The extent to which producers in these other nations find it advantageous to diversify into sablefish culture depends in large part upon the extent of the market. As production grows the price will decline, and the profits dwindle. If the market for high quality sablefish remains largely a Japanese market, then prices will fall in accordance with our price prediction model.

Finally, the growth in production by sablefish farmers will eventually slow to a halt when prices decline enough to snuff out farm profits. If the farmed fish are supplied just to the Japanese market, then we predict that the industry will reach a total output of between 27,000 mt and 48,000 mt, at which point the price will have dropped to between $1.67 and $2.05, making additional farming barely profitable. The sablefish farm sector could expand more, if other North American, European, or Asian markets for sablefish grow, either due to marketing efforts or due to simple population growth and decline in supply of competing ocean fish products. Market growth will certainly not be automatic, as there are other fish species vying for the white-fleshed marine fish segment of the market. Resourceful marketing efforts will need to accompany the expansion of the sablefish farming industry.

At the very least, we can expect a moderate level of sablefish culture to depress prices in the key Japanese market. At worst, the price of Alaskan sablefish will drop to between $1.67 and $2.05 per pound over the next 5-10 years, a 54% to 36% drop. Canadian prices would drop to the range of $2.04 to $2.49 C$/lb. Whether the farming of sablefish presents a serious threat to the sablefish fishery depends upon the marketing and technical issues discussed above. To remain a vibrant and profitable enterprise, the fishing industry may need to develop a marketing strategy to sell its product as different and especially desirable. Finally, and most speculatively, if the sablefish farming sector expands in British Columbia, a coordinated effort between the fishing and farming interests to control that expansion and to expand marketing efforts could forestall the more dire predicted effects on market price.

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TECHNICAL APPENDIX

Statistical Model

The basic model is a system of five structural equations describing supply and demand in Japan, and ex-vessel prices in North America. In this appendix, we will describe in detail the two variants of the basic 5-equation model (Model 1 and Model 2) presented in the text.

The variables used in both models are described in Table A1.

Table A1. Variables used in structural model of sablefish market. Endogenous variables are in boldface.

Qsabimp	Annual Japanese Import Quantity of Sablefish, measured in metric tonnes
TAC	Total Allowable Catch in all Fisheries Combined, metric tonnes
P_tcwm	Real price of sablefish (Yen per kg) in the Tokyo Central Wholesale Market. Price is deflated with the Japanese consumer price index, base year 2000.
P_tcwm_US	Real price of sablefish in the Tokyo Central Wholesale Market, converted to US dollars using the real exchange rate.
P_tcwm_CA	Real price of sablefish in the Tokyo Central Wholesale Market, converted to Canadian dollars using the real exchange rate.
P_xvak	Real ex-vessel price in Alaska (Gulf of Alaska and Bering Sea combined) in US dollars per kg round weight. Fixed gear fishery only. Price is deflated with the US producer price index, base year 2000.
P_xvpc	Real ex-vessel price for Pacific Coast (Washington, Oregon, and California) in US dollars per kg round weight. Fixed gear fishery only. Price deflated with the US producer price index, base year 2000.
P_xvbc	Real ex-vessel price for British Columbia, in Canadian dollars per kg round weight. Fixed gear fishery only. Price deflated with the Canadian producer price index, base year 2000.
Income	Real per capita GDP (=GDE), deflated with the Japanese consumer price index. Model 1 only.
P_sok	Real price for Pacific sockeye salmon in Japan (Yen per kg). Model 1 only.
Exch	Nominal Yen/US dollar exchange rate (Yen per US dollar).
IncDev	Deviation of per capita GDE from its 1987-2002 trend. Model 2 only.
IFQUS	Dummy variable for the US IFQ system in Alaska. Equals 0 from 1987 to 1994, equals 1 from 1995 to 2002.
IVQBC	Dummy variable for the Canadian IVQ system. Equals 0 from 1987 to 1989, equals 1 from 1990 to 2002.

The 5 equations are outlined below, in three groups:
a. supply,
b. demand, and
c. ex-vessel equations.

a. Supply in Japan

The first equation is a supply relation, describing the imported supply of sablefish to Japanese markets as a function of the Total Allowable Catch (TAC) in the North American fishery.

$$Qsabimp = \alpha_0 + \alpha_1 * TAC$$

In general, the quantity of sablefish caught can be treated as an exogenous variable, since the total level is set by regulation. In more recent years, since IFQ's have been in place, there may be a very small price/quantity supply relation . In the pre-IFQ era, landings were very close to total allowable catch, and sometimes exceeded TAC. Since IFQ's have been in place, some amount of quota has remained unfished each year, sometimes over 20%. Although it is possible that this result is simply an institutional artifact (that is, quota may have been allocated to individuals who had no intention of fishing it and instead viewed it only as a capital asset), it is also possible that price signals are dictating supply choices. However, we were unable to find a direct statistical relation between ex-vessel prices and landed quantities. Therefore, our supply relation uses TAC as an exogenous variable affecting Japanese import quantity.

b. Demand in Japan

The second equation describes the determination of sablefish prices in the Japanese consumer market. This is the only equation which differs between Model 1 and Model 2, described in detail below.

In Model 1, we have a standard inverse demand relation. Price is determined by the per capita quantity in the market (kg per person), the price of substitutes, and per capita income.

Model 1:

$$P\_tcwm = \beta_{10} + \beta_{11} * (Qsabimp * 10\char`^3 / jpop) + \beta_{12} * (Income) + \beta_{13} * (P\_sok)$$

In model 2, we add variables which describe more closely some of the major macroeconomic events in Japan during the 1990's. Since all sablefish is imported, its real price to Japanese consumers should be strongly affected by changes in the foreign exchange rate. In addition, the two recessions of the 90's were marked by rapid reversals of productivity trends, which can be measured using the deviation of per capita GDP from it's longer-term trend. When these variables were added to Model 1, income and the price of substitutes became insignificant, and so only the two new variables were retained in Model 2.

Model 2:

$$P\_tcwm = \beta_{20} + \beta_{21} * (Qsabimp * 10\text{^}3 / jpop) + \beta_{22} * (Exch) + \beta_{23} * (IncDev)$$

c. Ex-vessel Price Equations

We divided the sablefish fishery into its three regulatory/geographic units, because these are natural divisions, and because visual inspection of the data showed that prices were fairly homogeneous within each unit but quite different between units. As discussed above, we assume that supply is exogenous, and in none of the fisheries could we find a significant positive relation between price and landings. Thus, the overriding determinant for ex-vessel price is ultimate demand in Japan. We therefore modelled ex-vessel prices as simple linear proportions of the price in Tokyo. No lagged values of the Tokyo price were significant. We added a price-by-IFQ interaction term, to capture any change in price received by fishermen that may have resulted from the IFQ system. At first, we put both dummy variables in all three equations, so as not to preclude spillover effects between markets. There were no spillover effects on price between countries, but the Pacific Coast fishery benefitted a small amount when Alaska adopted IFQ's. Only the significant effects were retained in the equations, and so the insignificant constant terms were also removed. The final specifications are therefore:

Alaska Ex-vessel:

$$P\_xvak = \gamma_{11} * P\_tcwm\_US + \gamma_{12} * IFQUS * P\_tcwm\_US$$

Pacific Coast Ex-vessel:

$$P\_xvpc = \gamma_{21} * P\_tcwm\_US + \gamma_{22} * IFQUS * P\_tcwm\_US$$

British Columbia Ex-vessel:

$$P\_xvbc = \gamma_{31} * P\_tcwm\_CA + \gamma_{32} * IVQBC * P\_tcwm\_CA$$

Annual vs Quarterly Analysis

We used annual data from 1987 to 2003 to estimate the equations described above. Before finalizing upon annual data, we tried numerous specifications using quarterly data. The timing of the harvest has changed over the years, and we hoped to capture that source of variation in price. However, in order to capture the effect of short term product flows, it would be necessary to include information on cold storage holdings. We collected month-end sablefish cold storage holdings data for the United States from reports issued by the U.S. Department of Commerce's

Current Fisheries Statistics program. Unfortunately, these data are likely to be incomplete, as reporting is voluntary. A comprehensive analysis would also require information on cold storage holdings in Japan. We found inventory data for several important groups of fish in Japan (salmon, tuna), but sablefish was not included.

Because frozen sablefish is normally stored between quarters, the relationship between monthly wholesale price and import quantity is not necessarily strong. The residuals from our quarterly regressions were indeed large. Including lag values for import quantity improved the fit; however, we then determined that the quarterly model had no advantages over an annual model, and instead only added autoregressive serial correlation problems to the regressions. Thus, we chose to use annual data. Further support for this decision comes from the fact that supply (TAC) is announced *prior* to the beginning of the season. Therefore fishermen, packers, importers and wholesalers will all have quite accurate expectations of annual supply. This should serve to further dampen the importance of quarterly variations in quantity, in addition to the smoothing effect that cold storage can achieve.

Estimation Procedure

In the system described above, some endogenous variables appear as explanatory variables in other equations, and so it was necessary to use instrumental variable simultaneous estimation methods. For both models, 3-stage-least-squares (3SLS) was used to achieve efficient standard errors. All the exogenous variables were used as instruments. We used Eviews 4.1 for the estimations.

Coefficients were estimated for the base period (1987 - 2003), and then a model object was created in Eviews from the estimated relationships. Stochastic simulations involving several levels of increased supply were run for each of the two systems of equations described above (Models 1 and 2). We modeled supply increases as increases in the total allowable catch. Implicitly, this assumes that the additional supply (*ie*. aquaculture fish) is equivalent to wild-caught fish, from the point of view of the Japanese consumer. Currently, there is no information available regarding the preferences of the Japanese for aquaculture versus wild sablefish. It is known that larger fish with firm flesh tend to be more valued, but there are no information sources where the market data on both price and quantity are separated by fish size/quality. Therefore, even if we knew the characteristics of aquaculture sablefish, it would not be possible to differentiate them in our market model at this time.

In order to run these simulations, it was necessary to provide values for the exogenous variables in the system; that is, we had to specify values for sockeye salmon, the foreign exchange rate, Japanese income, etc. We chose our background to be the average conditions experienced over the past three years (2001 - 2003). Thus, our starting supply is the average from 2001 to 2003 (= 27,964 metric tonnes), and each supply scenario assumes that nothing else changes except the total supply. This is therefore not a forecast of expected prices *n* years from now; instead, it answers the question "what would be the price now if the supply was X tons more?".

Coefficient Estimates

The two models performed similarly with respect to coefficient estimates and diagnostic statistics. Below, we present the estimated coefficients (with t-statistics in brackets), R-squared for each equation, and the Durbin-Watson statistic.

Table A2: Coefficient Estimates for Model 1

$$Qsabimp = -6504 + 0.734 * TAC$$

t-stat: (-2.47) (10.41) Adj R^2 = 0.85 DW = 2.40

$$P\_tcwm = -2.13 * (Qsabimp * 10^\wedge 3 / jpop) + 344 * (Income) + 0.162 * (P\_sok)$$

t-stat: (-4.87) (24.62) (2.31)
Adj R^2 = 0.71 DW = 1.70

$$P\_xvak = 0.292 * P\_tcwm\_US + 0.353 * IFQUS * P\_tcwm\_US$$

t-stat: (23.86) (23.76)
Adj R^2 = 0.98 DW = 1.71

$$P\_xvpc = 0.231 * P\_tcwm\_US + 0.098 * IFQUS * P\_tcwm\_US$$

t-stat: (31.96) (11.76)
Adj R^2 = 0.95 DW = 1.42

$$P\_xvbc = 0.458 * P\_tcwm\_CA + 0.056 * IVQBC * P\_tcwm\_CA$$

t-stat: (19.9) (2.36)
Adj R^2 = 0.94 DW = 1.78

Table A3: Coefficient Estimates for Model 2

$$Qsabimp = -6573 + 0.736 * TAC$$

t-stat: (-2.48) (10.36) Adj R^2 = 0.85 DW = 2.40

$$P\_tcwm = 1265 - 2.827 * (Qsabimp * 10\text{^}3 / jpop) + 2.571 * (Exch) + 314 * (IncDev)$$

t-stat: (11.65) (-8.59) (2.82) (2.73)
Adj R^2 = 0.80 DW = 2.02

$$P\_xvak = 0.293 * P\_tcwm\_US + 0.351 * IFQUS * P\_tcwm\_US$$

t-stat: (24.18) (24.01)
Adj R^2 = 0.98 DW = 1.69

$$P\_xvpc = 0.231 * P\_tcwm\_US + 0.098 * IFQUS * P\_tcwm\_US$$

t-stat: (30.51) (10.76)
Adj R^2 = 0.95 DW = 1.42

$$P\_xvbc = 0.460 * P\_tcwm\_CA + 0.054 * IVQBC * P\_tcwm\_CA$$

t-stat: (19.84) (2.26)
Adj R^2 = 0.94 DW = 1.79

Model 2 performed slightly better with respect to the demand equation, with a higher adjusted R^2 statistic and improved Durbin-Watson. The coefficient on quantity also has a somewhat higher t-statistic, but there is little else to differentiate the two systems with respect to regression fit.

Table A4. Data Sources. Data were obtained from sources listed in the following table. More detailed descriptions are to be found within the data files.

Data	Source
U.S. Sablefish Landings and Landed Values	PacFIN Database, Pacific States Marine Fisheries Commission, 2003
Canada Sablefish Landings and Landed Values	Department of Fisheries and Oceans Canada, 2003
Alaska Total Allowable Catch	North Pacific Fishery Management Council
Pacific Coast Total Allowable Catch	Pacific Fishery Management Council
Canada Total Allowable Catch	Department of Fisheries and Oceans, 2002/2003 Stock Assessment Report (Kronlund *et al.*, 2003)
Sablefish Wholesale Prices and Quantities in Japan	Sonu, 2000 and pers.comm. Hastie, 1989
Sablefish Import Prices and Quantities in Japan	NMFS “Japanese Market News” web site (1995-2003); Bill Atkinson’s News Report (1987-1995)
Sockeye and Mero Prices	Bill Atkinson's News Report, 1987 - 2003; NMFS “Japanese Market News” web site
Japanese Price Indices Japanese Population Size	Japanese Statistics Bureau
Japanese GDP, historic	Economic and Social Research Institute, Japan
US/Japan Foreign Exchange Rate US/Canada Foreign Exchange Rate	U.S. Federal Reserve
US Producer Price Index	US Bureau of Labor Statistics
Canada Producer Price Index	Statistics Canada
Canada/Japan Foreign Exchange Rate	Bank of Canada

Table A5. Description of data given in Table A6.

Tables A5 (a) through A5 (d) describe the variables presented in Tables A6 (a) through A6 (d). This includes variables used directly in regressions, as well as the raw data used to calculate some variables. Variables with asterisks (*) are those used directly in the regressions.

Table A5 (a)	
Vsabimp	Total value imported sablefish, million yen
* qsabimp	Total quantity imported sablefish, metric tonnes
p_imp	Real import price of sablefish, yen per kg
Vsabtcwm	Total wholesale value in TCWM, million yen
qsabtcwm	Total quantity sold in TCWM, metric tonnes
* p_tcwm	Real wholesale price of sablefish, yen per kg
* p_sok	Real import price of imported Pacific Sockeye, yen per kg
Vmeroimp	Total value imported mero, million yen
qmeroimp	Total quantity imported mero, metric tonnes
p_mero	Real import price of imported mero, yen per kg

Table A5 (b)	
VNbs	Total landed value of sablefish, Bering Sea fixed gear fishery, nominal US dollars
qNbs	Sablefish Landings, Bering Sea fixed gear, metric tonnes round weight
VNga	Total landed value of sablefish, Gulf of Alaska fixed gear fishery, nominal US dollars
qNga	Sablefish Landings, Gulf of Alaska fixed gear, metric tonnes round weight
VNpc	Total landed value of sablefish, Pacific Coast fixed gear fishery, nominal US dollars
qNpc	Sablefish Landings, Pacific Coast fixed gear, metric tonnes round weight
VNbc	Total landed value of sablefish, British Columbia fixed gear fishery, nominal Cdn dollars
qNbc	Sablefish Landings, British Columbia fixed gear, metric tonnes round weight

Table A5 (c)	
VNak	Total landed value of sablefish, Alaska fixed gear fishery, US dollars (Bering Sea plus GoA)
qNak	Sablefish Landings, Alaska fixed gear, metric tonnes round weight (Bering Sea plus GoA)
* p_xvbc	Real ex-vessel price for sablefish, B.C. fixed gear fishery, Cdn. dollars per kg round weight
* p_xvak	Real ex-vessel price for sablefish, Alaska fixed gear fishery, US dollars per kg round weight
* p_xvpc	Real ex-vessel price for sablefish, Pacific Coast fixed gear fishery, US$ per kg round weight
* ifqus	Dummy for Alaska IFQ's.
* ifqbc	Dummy for British Columbia IVQ's.
tacpc	Total Allowable Catch, Pacific Coast Fishery (metric tonnes)
tacga	Total Allowable Catch, Gulf of Alaska Fishery (metric tonnes)
tacbs	Total Allowable Catch, Bering Sea Fishery (metric tonnes)
tacbc	Total Allowable Catch, British Columbia Fishery (metric tonnes)
* tac	Total Allowable Catch, All Fisheries Combined (metric tonnes)

Table A5 (d)	
usppi	U.S. Producer Price Index, All Commodities.
cppi	Canadian Industrial Product Price Index, All Products
jcpi	Japanese Consumer Price Index
jpop	Japanese Population, in thousands (all ages)
ca_us	Canada/US Nominal Dollar Exchange Rate
yen_ca	Yen/CdnDollar Nominal Exchange Rate
* yen_us	Yen/USDollar Nominal Exchange Rate
jgdp_def	Japanese GDP deflator
jgdp_n	Japanese Nominal GDP, billion yen
* jgdp_rpc	Real per capita GDP in Japan, million yen per person
jgdptrnd	Linear trend in Japanese real per capita GDP, 1987-2003
* jgdpdev	Deviation of per capita GDP from 1987-2003 trend, million yen per person

Table A 6. Data Used in Sablefish Market Analysis.

See Table A5 for explanation of variables.

Table A6 (a)

year	Vsabimp	qsabimp	p_imp	Vsabtcwm	qsabtcwm	p_tcwm	p_sok	Vmeroimp	qmeroimp	p_mero
1987	16990	28583	686	7055.363	9149	889	1126			
1988	20374	30558	764	6282.601	7815	921	1402			
1989	18502	29353	706	7444.458	9328	894	1083			
1990	18157	26447	745	13531.440	14456	1016	961			
1991	21449	24277	929	13088.590	10870	1266	695			
1992	15826	20138	813	7886.322	7452	1094	845			
1993	17288	25720	686	7323.389	8717	857	526			
1994	15663	21098	753	7843.487	7634	1042	620			
1995	15437	20061	781	6711.566	6542	1042	453			
1996	18641	18840	1003	8373.429	7046	1205	578	8792	11130	801
1997	16497	14609	1125	7041.615	5026	1395	620	12011	13768	869
1998	15105	15749	950	5473.221	4646	1166	882	8022	9645	824
1999	13987	15397	902	7253.249	6434	1119	634	10167	8783	1150
2000	14110	14144	998	6980.380	5625	1241	497	7281	6451	1129
2001	14255	13969	1028	6245.578	4937	1274	525	5304	5328	1002
2002	13475	12292	1114	6910.320	5228	1343	509	5471	4660	1193
2003	13247	12318	1096			1318	503	3074	2388	1312

Table A6 (b)

year	VNbs	qNbs	VNga	qNga	VNpc	qNpc	VNbc	qNbc
1987	7339987	5380.072	36299899	23505.980	8718766	6305.694	13829566.5	4182.907
1988	8593332	4067.014	57825735	26832.050	8277368	5562.469	17127769.23	4538.050
1989	4844052	2729.678	50282029	26245.160	6030433	4748.558	13803909.78	4723.099
1990	5112720	3183.081	37037134	24557.910	5656724	4121.861	18633575.56	4532.161
1991	6793009	2732.471	48263894	21965.030	9875430	4616.576	28444471.41	4967.894
1992	5169189	1929.128	43344017	19203.380	7949317	4025.616	24471783.16	4825.176
1993	4872159	2252.148	45563670	21424.670	5497178	3203.786	22488150.34	4625.661
1994	5203520	1881.291	71941994	21962.720	7986889	3768.448	31381428.94	4695.913
1995	12231613	1864.958	134684472	19456.100	13584914	4068.358	30736174.5	4064.843
1996	8854725	1339.496	110255297	16358.320	15102871	4118.817	23748630.13	2977.003
1997	10423799	1331.000	114031140	14816.420	17614761	4173.594	31319047.38	3699.319
1998	5135685	1052.058	75269879	14105.490	6098801	2211.720	25915255.94	3985.819
1999	7555994	1233.865	78933238	12450.130	10320000	3476.008	26704828	3647.417
2000	10797084	1552.449	103125728	13147.320	13177988	3567.855	24109115	2602.670
2001	9526031	1498.660	83226411	12268.410	10781710	3035.573	20999962	2454.406
2002	13263519	1978.700	85328684	12239.980	8048963	2221.238	15852578	1752.316
2003	14718483	1921.960	107514107	13830.160	12086080	3080.297	14402000	2065.000

Table A6 (c)

year	VNak	qNak	p_xvbc	p_xvak	p_xvpc	ifqUS	ifqBC	tacpc	tacga	tacbs	tacbc	tac
1987	43639888	28886.050	4.46	1.95	1.78	0	0	12000	20000	7700	4100	43800
1988	66419068	30899.060	4.88	2.67	1.85	0	0	10000	28000	8400	4400	50800
1989	55126080	28974.840	3.71	2.25	1.5	0	0	9000	26000	6200	4400	45600
1990	42149856	27740.990	5.2	1.73	1.57	0	1	8900	26000	7200	4670	46770
1991	55056904	24697.500	7.32	2.54	2.44	0	1	8900	22500	6300	5000	42700
1992	48513208	21132.510	6.45	2.6	2.24	0	1	8900	20800	4400	5000	39100
1993	50435828	23676.820	5.97	2.38	1.91	0	1	7000	20900	4100	5000	37000
1994	77145512	23844.010	7.74	3.57	2.34	0	1	7000	25500	3340	5000	40840
1995	146916080	21321.060	8.15	7.33	3.55	1	1	9100	21500	3800	4140	38540
1996	119110024	17697.820	8.56	6.99	3.81	1	1	9100	17080	2300	3600	32080
1997	124454936	16147.420	9.02	8.02	4.39	1	1	9100	14520	2300	4500	30420
1998	80405568	15157.550	6.9	5.66	2.94	1	1	5200	14120	2680	4500	26500
1999	86489232	13683.990	7.63	6.68	3.14	1	1	9700	12700	3200	4500	30100
2000	113922816	14699.770	9.26	7.75	3.69	1	1	9700	13330	3900	4000	30930
2001	92752440	13767.080	8.47	6.66	3.51	1	1	7661	12840	4060	2800	27361
2002	98592200	14218.680	8.95	7.02	3.67	1	1	4786	12820	4480	2450	24536
2003	122232592	15752.120	7.00	7.46	3.77	1	1	8460	14890	6000	2646	31996

Table A6 (d)

year	usppi	cppi	jcpi	jpop	ca_us	yen_ca	yen_us	jgdp_n	jgdp_def	jgdp_rpc	jgdptrnd	jgdpdev
1987	0.775	0.741	0.867	122264	1.326	108.775	144.602	352530.0	0.942	3.32566	3.691391	-0.3657
1988	0.806	0.773	0.873	122783	1.231	104.053	128.174	379250.4	0.949	3.53813	3.719467	-0.1813
1989	0.846	0.788	0.893	123255	1.184	116.295	138.074	408534.7	0.971	3.71170	3.747543	-0.0358
1990	0.876	0.791	0.921	123611	1.167	123.718	144.999	440124.8	0.995	3.86598	3.775619	0.0904
1991	0.878	0.782	0.951	124043	1.146	117.348	134.591	468234.4	1.024	3.96927	3.803695	0.1656
1992	0.883	0.786	0.967	124452	1.209	104.757	126.780	480492.1	1.041	3.99262	3.831771	0.1608
1993	0.896	0.815	0.98	124764	1.290	85.775	111.076	484233.8	1.046	3.96041	3.859847	0.1006
1994	0.907	0.864	0.986	125034	1.366	74.664	102.179	490005.3	1.047	3.97462	3.887923	0.0867
1995	0.940	0.928	0.985	125570	1.373	68.041	93.965	496922.2	1.042	4.01760	3.915999	0.1016
1996	0.962	0.932	0.986	125864	1.364	79.679	108.780	509984.0	1.033	4.10940	3.944075	0.1653
1997	0.962	0.939	1.004	126166	1.385	87.309	121.058	520937.3	1.036	4.11253	3.972151	0.1404
1998	0.937	0.942	1.01	126486	1.484	87.799	130.989	514595.4	1.035	4.02812	4.000227	0.0279
1999	0.946	0.959	1.007	126686	1.486	76.285	113.734	507224.3	1.021	3.97596	4.028303	-0.0523
2000	1	1	1	126926	1.486	72.576	107.804	511462.4	1	4.02961	4.056379	-0.0268
2001	1.011	1.010	0.993	127291	1.549	78.403	121.568	505847.4	0.985	4.00196	4.084455	-0.0825
2002	0.988	1.010	0.984	127435	1.570	79.653	125.220	498102.0	0.974	3.97223	4.112531	-0.1403
2003	1.041	0.997	0.981	127620	1.401	82.724	115.939	499052.7	0.950	3.98620	4.140606	-0.1544