TUNA PRICE IN RELATION TO ECONOMIC FACTORS AND SEA SURFACE TEMPERATURE IN FRESH TUNA MARKET

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ABSTRACT

This study analyzes the main factors that affected seasonal variation of fresh tuna price through a statistical approach. The study concludes that seasonal variation in the volume of landings by Hawaii-based vessels is the predominant factor affecting seasonal variation in price for most of the tuna, but that price variation is less than volume variation. In addition, the quality of bigeye appears to have a seasonal pattern that is strongly correlated with sea surface temperature leading to seasonal variation in bigeye tuna price. Substitution effects are found within certain species groups that have similar end uses. Holidays (Christmas and New Year's) and the number of tourists coming from Asia are also associated with variations in bigeye and yellowfin tuna prices. These price relationships upon the analyses might be useful to fisheries management since they can be used to predict how fish market responses to regulation change and revenue change to the fisheries industry.

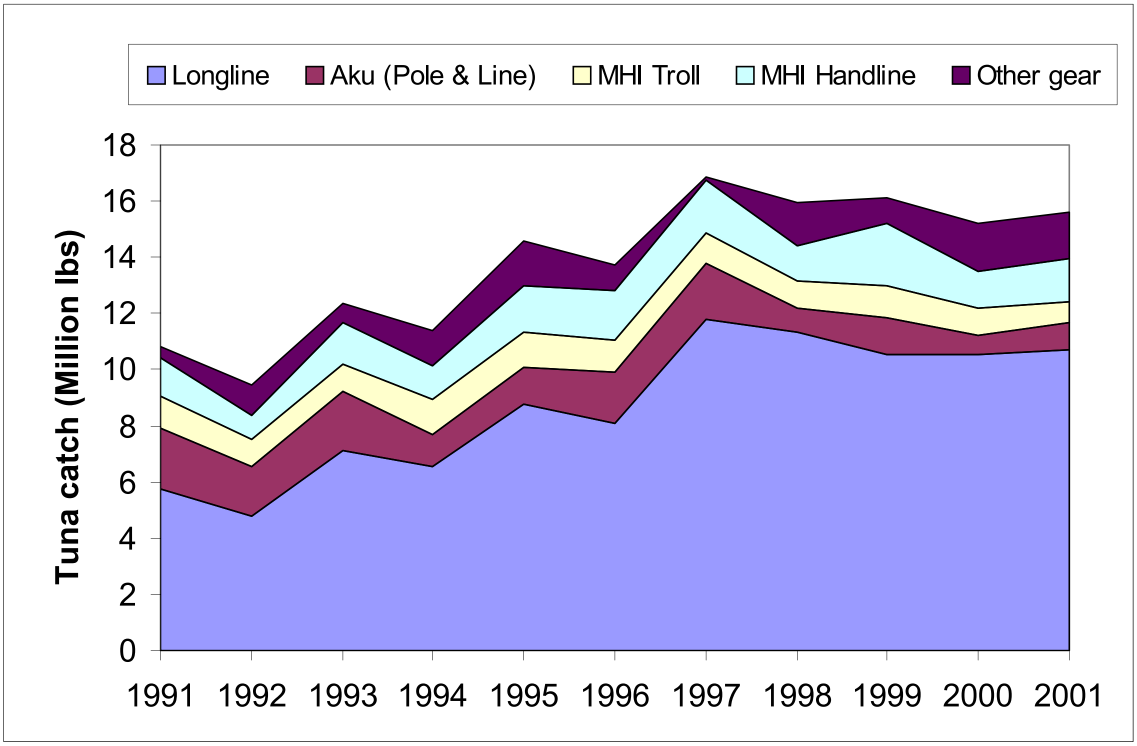
Keywords: Fishery; Tuna Price; Hawai`i Market;

Fresh tuna makes up the largest segment of Hawai`i's fish production and is a primary source of fresh fish to the local market. In 2001, commercial tuna landings totaled 14.4 million pounds and represented 61% of total commercial landings. The landings were worth $33 million and equivalent to 68% of total revenue in Hawai`i (WPRFMC, 2003). The majority of tuna was retained in the local market, but a substantial portion was exported to foreign countries and the U.S. mainland. This paper provides a brief overview of markets and price determinations for tuna harvested from Hawai`i's fisheries. This information is important for decision-making to both fishermen and fishery managers.

TUNA PRODUCTION

Tuna is harvested and sold fresh by local fishers in Hawai`i. Its production has been on an increasing trend, rising from 9.4 to 14.4 million pounds in recent years (1991 to 2001). Longline is the main fishing gear used for harvesting tunas, while handline, troll, and pole and line (aku boat) fisheries also supply a significant amount of tunas to the market. Figure 1 illustrates tuna landings by different gear types during 1991-2001.

Bigeye and yellowfin are the main tuna species harvested by Hawai`i fleets, although species composition has changed over time. Figure 2 illustrates species composition of Hawai`i commercial tuna catches in 1991 vs. 2001. In the early 1990s, yellowfin landings were slightly greater than bigeye landings, 35% and 33% of total tuna catches, respectively. Skipjack was third at 24%, after having been the main species before the pole and line fishery began its decline in the 1980s. Bigeye and albacore catches have since grown substantially because of the steady growth of the longline fleet. Bigeye became the largest component of the tuna catches in 2001 with 39% of total tuna catches, followed by yellowfin and albacore.



Data sources: WPRFMC, 2001, Pelagic Fisheries of the Western Pacific Region 2001 Annual Report.
Figure 1. Hawai`i commercial tuna catches by gear type, 1991-2001

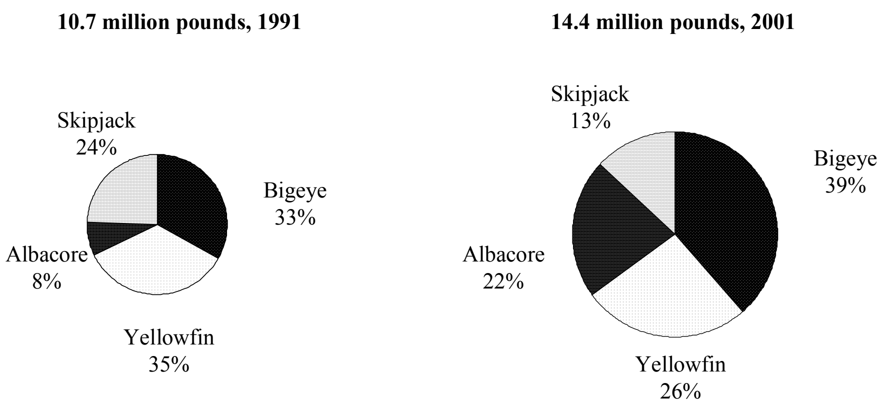


Figure 2. Species composition of Hawai`i commercial tuna catches, 1991 vs. 2001

EX-VESSEL PRICE AND REVENUE

Tuna prices vary by species and condition in the Hawai`i's market. In 2001, bigeye and yellowfin were high value species with average ex-vessel prices[1] of $3.35 and $2.29 per pound, respectively. The average prices of albacore and skipjack were substantially lower at around $1.10 per pound. Bluefin tuna was also caught, but in very limited quantities. It received the highest ex-vessel price among all tunas at $5.00 per pound.

Revenue from bigeye was the leading component of revenue in the tuna industry due to a large volume of landings and high price (Table 1). Ex-vessel revenue of bigeye catch was $18.7 million, or 57% of the total revenue of all tunas harvested in 2001. While yellowfin and albacore were similar in catch range, yellowfin brought in $8.7 million, less than half that of bigeye but twice the revenue of albacore. Revenue from skipjack was about $2 million.

Table 1. 2001 Hawai`i domestic commercial tuna catches, revenue and prices

Species	Pounds Caught (x 1,000 lbs)	Ex-vessel Revenue (x $1,000)	Ex-vessel Price ($/lb)
Total tunas	14,406	32,981	2.29
Albacore	3,139	3,486	1.11
Bigeye	5,572	18,656	3.35
Bluefin	2	10	5.00
Skipjack	1,891	2,113	1.12
Yellowfin	3,802	8,716	2.29

Data sources: WPRFMC, 2003, Pelagic Fisheries of the Western Pacific Region 2001 Annual Report.

MARKETS AND DISTRIBUTION

Hawai`i commercial fishers sell all of their tunas fresh and enjoy the benefit of a well-developed seafood marketing sector. The marketing and distribution system in Hawai`i is a part of a larger network of interconnected local and worldwide components that supplies a variety of fresh and frozen products to consumers in Hawai`i and elsewhere. Hawai`i's fish auction, the United Fishing Agency (UFA) auction in Honolulu, is the focal point of the Hawai`i market. It plays a critical role in local markets by handling a large quantity of fresh fish harvested by local fishers. The auction is conducted with open bids; fishers then pay a commission of approximately 10% of the sale price to the auction. The auctions provide buyers with an opportunity to inspect fish closely prior to purchase. Purchasers are allowed to grade the fish for quality before entering a bid. Fish are mostly sold individually although small-sized skipjack are sold in lots.

Historically, there was a strong system of bilateral exchanges (fishers contract directly with wholesalers and exporters) (Pooley, 1986), but the auction is clearly the predominant recipient of fresh tuna at present. While most of the tuna is consumed in the local market, there is a substantial amount of tuna exported to foreign countries and the U.S. mainland (Bartram, 1997). The mainland exports are inadequately

[1] Average price is calculated as (Ex-vessel revenue / Pound sold); price through out this article is round (whole) weight price.

documented, and consequently the discussion of imports and exports in this paper is limited to foreign trade. Japan was the sole market for Hawai`i's exported tunas prior to 1997, but in recent years exports to other countries such as Canada and Spain have gradually increased. Fresh tunas are mostly imported from the Indo-Pacific region, including Fiji, Tonga, Western Samoa, etc.

Throughout the period of 1991-2001, fresh tuna trade between Hawai`i and foreign countries was fairly balanced in terms of volume. Annual imports from foreign countries ranged from 0.7 million pound to 1.7 million pounds, with an average of 1.15 million pounds. In the same period, annual exports to foreign countries ranged from 0.5 million pounds to 2.1 million pounds, with an average of 1.08 million pounds. However, there were years when imports greatly exceeded exports and vice versa. Imports tend to be lower quality fish sold at discount prices.

PRICE VARIATION AMONG TUNAS

Tuna prices varied by species, reflecting market preferences and the ultimate uses of individual species. Table 2 illustrates the uses of tunas harvested by local fishers. In Hawai`i, as much as 40% of local tunas are consumed raw in the form of *sashimi* (raw cubes) and *poke* (raw cubes served with spices and condiments, a local favorite). The market for tunas served raw is generally known as the most demanding and requires high-quality fish. Other markets include cooking (highly variable in quality demanded), smoking, or drying (with the lowest quality requirements).

Table 2. Ultimate uses of tunas harvested in Hawai`i market

Species	Market name	Uses in Hawai`i	Export form
Bigeye	ahi	raw, cooking (fry & grill), drying, smoking	fresh
Yellowfin	ahi	raw, cooking (fry & grill), drying, smoking	fresh
Albacore	tombo ahi	cooking (fry & grill), raw	frozen, fresh
Skipjack	aku	raw, cooking (fry & grill)	fresh

In general, bigeye is the preferred market species among tunas harvested in Hawai`i, followed by yellowfin. Bigeye and yellowfin are commonly for *sashimi* and *poke,* although other tunas may used raw. Bigeye is the most preferred species because of its bright muscle color, high fat content, and long shelf life (Bartram *et. al*. 1996).

Skipjack tuna is commonly used for *sashimi* and is the preferred species for *poke*. Lower-quality skipjack is also smoked or dried (Bartram, 1997).

Albacore tuna has long been considered of lesser quality because of the light color of its muscle, but in recent years, its use has grown substantially. It is substituted in *poke* when other tuna is in short supply. Albacore with red muscle, which is somewhat unusual, may also be substituted for the preferred bigeye tuna in *sashimi*. In addition, a substantial market for albacore has developed with retailers who sell it for grilling. Lower-quality fish may be used for smoking, drying, or export to the U.S. mainland for canning (Bartram, 1997).

Due to less demand, albacore and skipjack prices are much lower than bigeye and yellowfin in Hawai`i. This price ranking of the four tuna species in the Hawai`i market is considerably different from what is observed in the worldwide market. In the worldwide market, albacore received the highest price, followed by yellowfin, bigeye, and skipjack. This is because tuna are commonly used in canneries outside of Hawai`i.

While tuna prices vary by species, individual fish prices within the same species vary substantially by their quality grades (McConnell, *et. al*., 1998, and Bartram, *et. al*., 1996). Tunas are graded into four levels (or quality grades) prior to sale, and the grading is based on weight (fish size), core temperature, muscle coloration, transparency, texture, and fat content. Harvest methods (gears) also affect the condition of the fish, the quality of the meat, and the size of fish caught. Fish quality grading also determines tuna usage. Within same specie, high-grade fish is served in raw markets while low-grade fish has other uses, such as cooking and drying.

SEASONAL VARIATION OF TUNA PRICES

Tuna prices also vary by season in Hawai`i market. The seasonal variation is attributable to changes in both quantity and quality of supply and changes in demand with holidays and tourist seasons. Since most of the tuna harvested in Hawai`i is sold locally, the volume of landings may have a great influence on local fish prices, especially in the short run where consumers' preference change is unlikely. Substitutes probably have important impacts on fish prices in the Hawai`i tuna market because some species have similar quality attributes and end-use to the consumers. Therefore, it is of interest to show how the price of an individual species responds to its own supply and the possible substitution among tuna species in the Hawai`i market. While all of these factors affect tuna pricing in general, individual species may be affected by various combinations of these factors. A previous study on yellowfin price in Hawai`i market (Pooley, 1991) also suggested that there might be factors that determine tuna price other than its own landings.

This study applied a price-dependent equation to examine the factors affecting seasonal variation of individual tuna price. The price-dependent equation is frequently estimated in agricultural economics where prices and quantities are determined recursively (Tomek and Robinson, 1990). In Hawai`i the quantities of local fish supply are largely limited by the capacity of current fleets and seasonal abundance of fish resources, thus, supply may not respond to price change in a short period (a week or even a month). Therefore, price is the logical dependent variable in the demand function, while the quantity of its own supply and quantities of the substitutes can be specified as independent variables. The price-dependent equation by species is:

$$P_j = \alpha_0 + \alpha_1 Q_{o_j} + \alpha_2 Q_{s_j} + \alpha_3 P_{j-1} + \alpha_4 SD + \ldots + \mu_j$$

where current and previous period of price in period *j* are P_j and $P_{j-1,}$ respectively; the Q_{oj} is landings of own species in period *j*; Q_{oj} is landings of substitutes in period *j*; the holiday dummy variable SD captures the period around the New Year (first two weeks and the last 3 weeks of the year); and μ_j is an irregular random component of all other effects. The data used for the analysis are based on the Hawai`i Division of Aquatic Resources (HDAR) commercial catch and sales report data in weekly increments for 1994-1996.

Yellowfin, Skipjack, and Albacore

As with other fresh products, supply and demand are important determinants of fresh tuna prices. Industry observers have noted that tuna pricing in the Hawai`i market is sensitive to supply, including its own supply and substitutes (Bartram, 1996). This relationship between volumes of landings and prices for yellowfin, skipjack, and albacore is illustrated in Figure 3 where price moves in the opposite direction as its own supply.

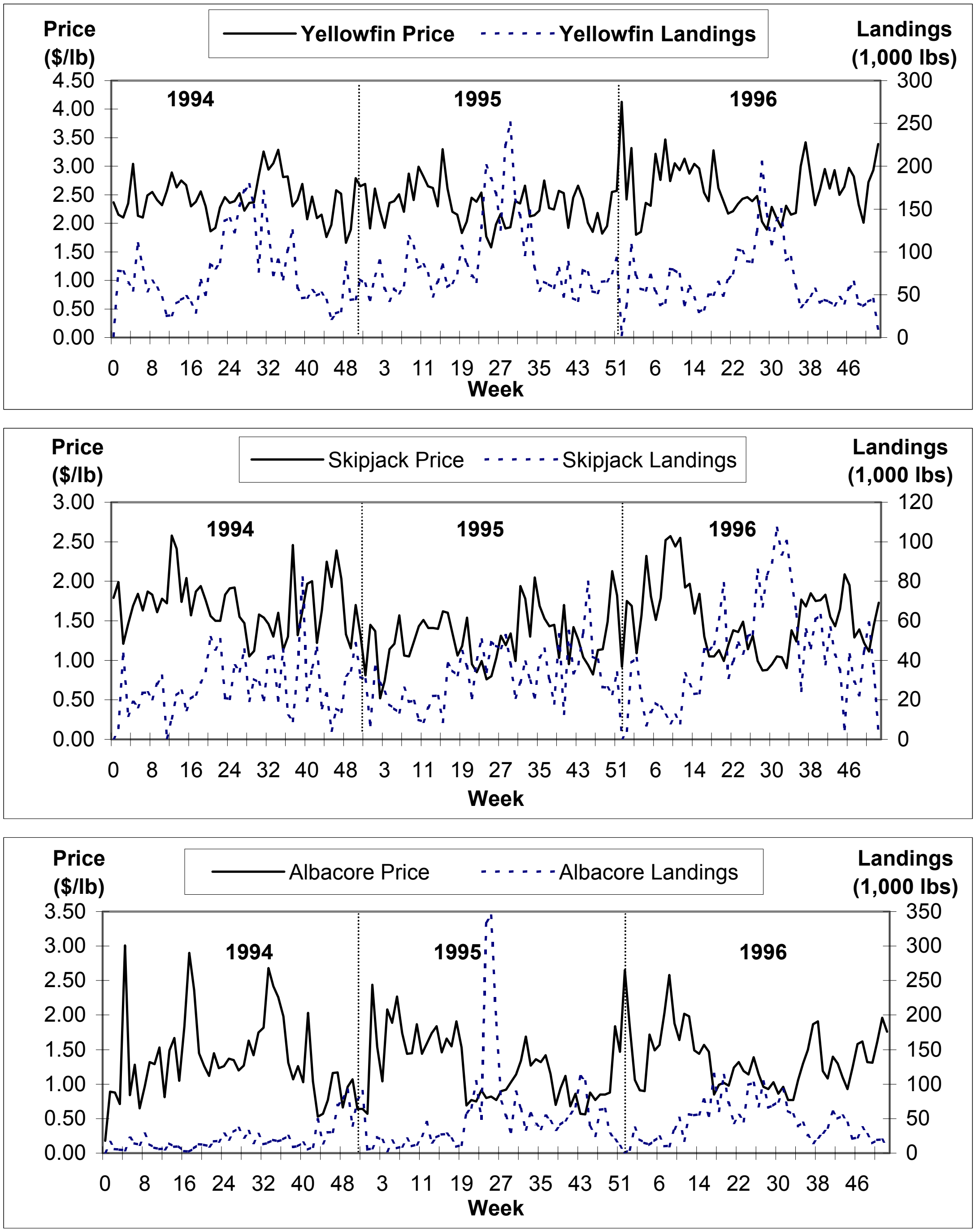


Figure 3. Weekly price and landings relationship for yellowfin, skipjack, and albacore

Table 3 presents the estimated price-dependent equations for the three tuna species, yellowfin, skipjack, and albacore, respectively. The statistical study found that supply (volume of landings) has a significant negative impact on tuna prices (negative coefficients with a 95% confidence or t-value greater than 1.96); a greater volume of local landings leads to lower prices for yellowfin, albacore, and skipjack.

Table 3. Estimates of price dependence equation of yellowfin, skipjack, and albacore

	Coefficient	t – Statistic
Yellowfin		
Constant	2.1403	9.807*
Yellowfin landings (1,000 lb)	-0.0025	-3.603*
One-week lagged price	0.3082	4.374*
Bigeye landings (1,000 lb)	-0.0022	-2.176*
Skipjack landings (1,000 lb)	-0.0031	-3.514*
Holiday dummy	0.3457	3.333*
R^2 adjusted	0.309	
DW-value	2.093	
Observations	158	
Skipjack		
Constant	1.3264	9.483*
Skipjack landings (1,000 lb)	-0.0065	-5.127*
One-week lagged price	0.4294	6.694*
Bigeye and yellowfin landings (1,000 lb)	-0.0014	-3.094*
Albacore landings (1,000 lb)	-0.001	-1.743**
R^2 adjusted	0.49	
DW-value	2.07	
Observations	158	
Albacore		
Constant	1.1828	7.553*
Albacore landings (1,000 lb)	-0.0023	-2.962*
One-week lagged price	0.4034	5.966*
Bigeye and yellowfin landings (1,000 lb)	-0.0013	-2.079*
Skipjack landings (1,000 lb)	-0.003	-1.783**
R^2 adjusted	0.358	
DW-value	2.103	
Observations	158	

* and ** indicate significant at 5% (t-value ≥1.96) and 10% (t-value ≥1.65) significance levels.

The substitution effect among tuna species is also significant as showed in the statistical analysis (Table 3). Landings of bigeye and skipjack appear to have a significant substitutive effect on yellowfin price since the coefficients of landings are negative with high t-value. This suggested that increased landings of bigeye or skipjack depressed yellowfin price. The sum of yellowfin and bigeye landings also had a negative impact on the prices of both skipjack and albacore. In addition, albacore and skipjack appeared to substitute each other, although the correlation was not very strong. However, albacore may not be a substitutive to yellowfin since albacore, unlike the other tunas, is not commonly used for raw consumption as discussed previously.

High demand during the holiday season (the three weeks around New Year) also affects the price of yellowfin significantly. In Hawai`i, Japanese year-end traditions stimulate yellowfin prices in the end of December. The high price carries over after the New Year because of the relatively low supply of high-quality fish and high tourist demand in the beginning of a year. However, neither skipjack price nor albacore price is significantly associated with the holiday demand, as the seasonal dummy variable (SD) was included into the equations.

Bigeye Price and Sea Surface Temperature

While the volume of landings (supply) is a major factor in the price fluctuations of yellowfin, skipjack, and albacore tunas, seasonal fish quality seems to have a greater impact on bigeye price. It was observed that the quality of bigeye is usually lower during the summer months and higher in winter seasons in the Hawai`i market. This change in bigeye quality may be associated with the seasonal patterns of ocean temperature since warmer water reduces fat content. Figure 4 illustrates the weekly price and landings of bigeye in a three-year period (1994-1996). This figure shows that the price of bigeye peaked in the winter season when the volumes of bigeye landings were heavy. However, price reached its lowest point in the summer when bigeye landings were low. This relationship between landings and price is different from the other three tuna species where a negative relationship exists and the normal supply-demand relationship can be clearly observed in the same type of graph (Figure 3).

What caused bigeye price to fall in a summer season when supply was low? Seasonal variation of fish quality affected bigeye price, and its impact on bigeye price concealed the impact of quantity. The statistical analysis demonstrates that the sea surface temperature [2] was significantly related to the price of bigeye in the Hawai`i market (Table 4). In this study, sea surface temperature is used as a proxy for the variations of bigeye quality. The estimated coefficient of sea surface temperature is –0.2089, which implies that sea surface temperature increases by one degree Fahrenheit may reduce bigeye price by $0.21. The higher the sea surface temperature, the lower bigeye quality would be and the lower of bigeye price was. While this also correlates with the increased competition from other species in the summer, it does appear to provide a measure of quality’s influence on price.

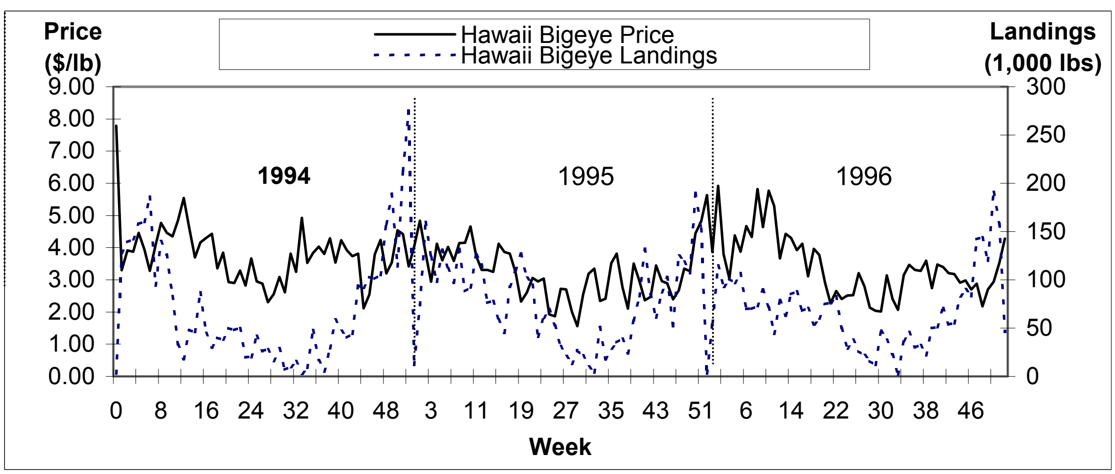


Figure 4. Price and landings relationship for bigeye in Hawai`i market

[2] The sea surface temperature used in the study refers to the weekly average sea surface temperature within 300 nautical miles around the Main Hawaiian Islands, the common fishing ground of Hawai`i fisheries for bigeye.

The statistical analysis also finds a significant negative relationship between the bigeye price and its supply (Table 4), but only if the quality attribute (sea surface temperature as proxy) is included in the function to estimate the price determinates. This implies that if fish quality did not change between seasons, the bigeye price would have been higher when its supply was low in the summer season.

Moreover, a large amount of yellowfin and skipjack landings significantly reduced the price of bigeye, implying that yellowfin and skipjack had substitutive effects on bigeye consumption. Due to the influence of the increased supply of yellowfin and skipjack in the summer season coupled with the lower quality of bigeye, the ex-vessel price of bigeye in summer season usually dropped $1 to $2 per pound compared to the other seasons. However, albacore was not a significant substitute for bigeye, as not to yellowfin.

Demand is another factor that significantly affected bigeye price. Holidays and an increase of visitors to Hawai`i boosted bigeye price. The impacts of holidays and tourist demand on fish prices were found only in yellowfin and bigeye markets, but not in skipjack and albacore markets. The bigeye price-dependent equation that included tourist demand is estimated by monthly data due to unavailability of weekly visitors. This implies that the increased demand during holiday seasons only applies to high quality tunas such as yellowfin and bigeye. Another finding on the demand side of the tuna market is that bigeye or yellowfin price was only affected by the number of Far Eastern visitors (mostly Japanese), but not the number of North American visitors (from mainland U.S. and Canada). This is almost certainly because *sashimi* consumption is more popular among visitors from Japan.

Table 4. OLS estimates of bigeye price-dependent equation

	Coefficient	t – Statistic
From weekly data		
Constant	8.6460	5.604*
Bigeye landings (1,000lb)	-0.0038	-3.182*
One-week lagged price	0.2773	4.231*
Yellowfin landings (1,000lb)	-0.0056	-4.471*
Skipjack landings (1,000lb)	-0.0055	-1.978*
Sea surface temperature	-0.2089	-3.741*
Holiday Dummy	0.5597	3.036*
R^2 adjusted	0.503	
DW-value	1.892	
Observations	158	
From monthly data		
Constant	11.6490	4.603*
Bigeye landings (1,000 lb)	-0.0010	-1.829**
Yellowfin landings (1,000 lb)	-0.0024	-3.688*
Skipjack landings (1,000 lb)	-0.0030	-2.133*
Sea surface temperature	-0.3062	-2.974*
No. of east-bound visitors (1,000)	0.0067	1.846**
R^2 adjusted	0.554	
DW-value	1.234	
Observations	36	

Industry also observed that yellowfin's on-board quality changed in different seasons; fish quality was better in winter than in summer. However, the statistical analysis suggests that sea surface temperature (as quality proxy) is not significantly correlated with price fluctuation of yellowfin. Yellowfin has a shorter shelf life and its color changes quickly after the fish is landed; the same market may not appreciate its initial quality and pay a price as high as bigeye's. As a result, yellowfin's price fluctuation is not significantly associated with the seasonal variation of fish quality, the element that apparently affected the seasonal variation of bigeye price.

This notable difference between bigeye price and yellowfin price in response to its own supply and fish quality was also observed in Japan's markets, where tunas are usually served raw. Based on information from the top 10 wholesale markets in Japan, bigeye price went up when its supply was high in winter season and went down when its supply was low in summer time (Figure 5a). However, yellowfin price usually moved up as its landings went down, and vice versa (Figure 5b). It appears that the seasonal variation of bigeye quality resulting from sea temperature change also played a significant role in bigeye price fluctuation in Japanese markets.

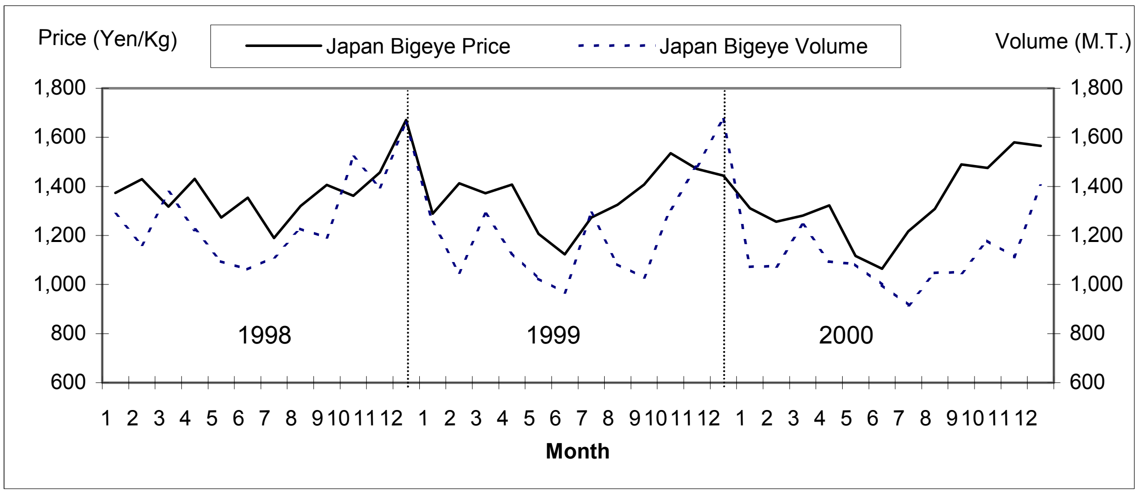


Figure 5a. Price and landings of bigeye in Japan 10 major wholesale markets, 1998-2000

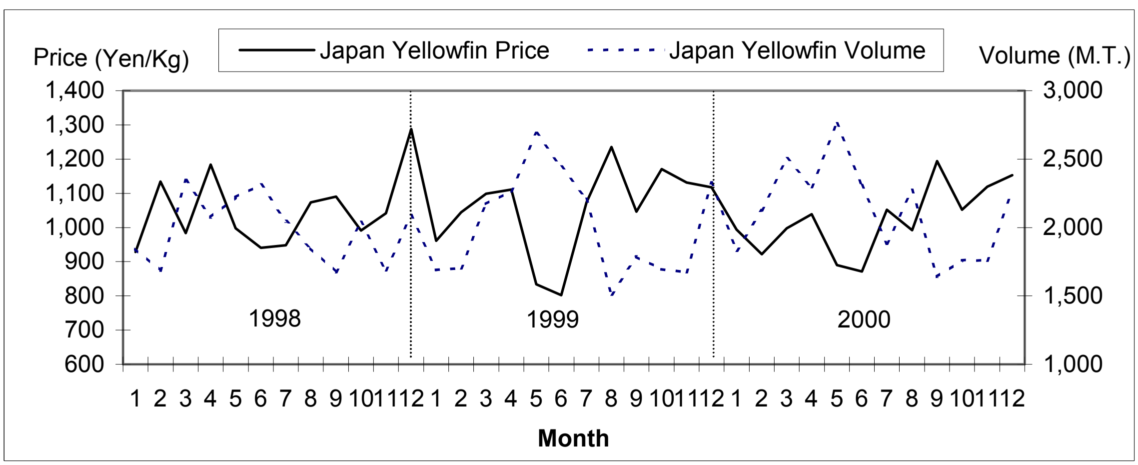


Figure 5b. Price and landings of yellowfin in Japan 10 major wholesale markets, 1998-2000
(Data source of Figures 5a and b: Japanese data publication "Suisanbusu Ryutu Tokei", downloaded from http://www.st.nmfs.gov/st1/market_news/

As discussed previously, seasonal variation of tuna prices is significantly correlated to several variables, including quantity of own supply and the substitutes, demand, and fish quality. However, these factors only explain about 50% of the weekly tuna price fluctuations in the Hawai`i market. Other elements, such as import and export markets and other unexpected variables, may also cause price fluctuations in a short-run. However, their impact on price cannot be quantified in the statistical analysis due to unavailability of the time-series data. Moreover, sea surface temperature was just a quality proxy of several quality attributes that affected seasonal fish quality. Further research is needed for a better understanding of seasonal changes in fish quality and the impacts on prices among various tunas.

Price Flexibility of Tunas

The price flexibility coefficient (F_p), defined as percentage change in price associated with the percentage change in quantity, is essentially the inverse of the demand elasticity. The price flexibility at the point of means can be calculated using the estimated quantity coefficient α_1 from the price-dependent demand function and the mean quantity ($\overline{Q}$) and price ($\overline{P}$) of a specific species:

$$F_p = \left(\frac{\Delta p}{\Delta Q}\right)\left(\frac{Q}{p}\right) = \alpha_1\left(\frac{\overline{Q}}{\overline{p}}\right)$$

The price flexibility coefficients for all tuna species (in absolute value) are all less than one (Table 5). This implies that price variation is less than supply variation in Hawai`i tuna market. It also indicates that the demand for tunas is elastic in Hawaii, meaning that the consumers will increase their purchase of tunas to a relatively greater extent if fish price declines, assuming auction prices translate to retail markets. In this case, tuna revenue increases if the volume of fish harvested increases, although this increase in supply leads to a decline in price.

Table 5. Price flexibility coefficients of tunas

Species	Estimated coefficient of landings	Mean weekly landings (1000 lbs)	Mean weekly price ($)	Price flexibility
Bigeye	-0.0038	72.34	3.50	-0.08
Yellowfin	-0.0025	76.72	2.46	-0.08
Skipjack	-0.0065	33.96	1.50	-0.15
Albacore	-0.0023	40.43	1.32	-0.07

CONCLUSIONS

Hawai`i tuna fisheries harvest mainly bigeye, yellowfin, albacore, and skipjack using various methods. While the local Hawai`i consumption of fresh tuna is the main market for the tuna harvested in Hawai`i, a substantial amount of tuna is exported. Tuna prices in Hawai`i vary by species due to market preferences and ultimate uses. Also, tuna prices fluctuate throughout the year due to changes in supply and demand, as well as seasonal changes in fish quality. The effect of seasonal fish quality on price was most evident with bigeye tuna; in fact, it was a principal influence on the price fluctuation. In contrast, seasonal variation in supply was a principal influence on the price fluctuations of yellowfin, skipjack, and albacore. However, price variation is less than volume variation.

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