State of Alaska | Walter J. Hickel, Governor

REGIONAL INFORMATION REPORT NO. 5J94-16

An Economic Analysis of Wholesale Pricing-By-Size for Alaskan Red King Crab:

Economic Implications of Reducing the Size Limit

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October 1994

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INTRODUCTION

The Alaskan king crab fishery began a precipitous decline in 1981. Following record harvests of 185 million pounds in 1980, statewide harvests declined to 16 million pounds by 1985. The fishery remains depressed today. There is an understandable tendency by industry participants and management agencies to focus on the effects of and remedies for depressed stock conditions. However, the collapse also altered the size and species distribution of the stocks. This change in distribution impacts not only prices received at the wholesale level, but also prices received at the exvessel level.

Both the National Marine Fisheries Service (NMFS) trawl survey data for Bristol Bay red king crab, *Paralithodes camtschaticus*, and actual fishery performance indicate that the average size legal crab is considerably smaller than in years prior to 1981. Smaller crab yield lower wholesale prices. And because exvessel price is dependent upon wholesale price expectations, the smaller crab translate into lower exvessel prices, even though crab are not graded by size at the exvessel level (Matulich et al. 1990).

As red king crab stocks diminished, many fishers turned to golden king crab, *Lithodes acquispinus* as a substitute. Though offsetting some of the lost red king crab revenues, economic theory suggests that the increased presence of smaller, less valuable golden crab probably depresses wholesale prices for red king crab because golden crab provide consumers a less expensive substitute.

Management strategies to rebuild this fishery or to increase industry revenues should consider the role of size and/or species distribution. Although both industry and regulatory agencies recognize that prices are affected by changing size and/or species distribution, neither is able to predict how market prices will react to changes in the distribution. It follows that neither is able to judge the merits of any potential management action that could alter the structure of harvest.

Previous economic analysis of the Alaskan king crab industry focused on bioeconomic models which integrate population dynamics models with exvessel and wholesale market models (Hanson 1987; Greenberg 1990). Both studies considered an aggregate king crab product at wholesale. Published data do not provide adequate detail on prices and quantities of king crab sold to estimate models of price determination by size and species. The research presented here attempts to model effects of size and species on wholesale price formation based on data collected directly from king crab processors.

Any study of price determination for food products graded by size or other quality aspects could provide direction for this research. However, literature reviewed focused on seafood products which are graded by size, namely groundfish, shrimp, and lobster. Price determination models for these species fall into three general categories:

1. Single equation models of price determination at one market level, such as exvessel or wholesale levels (Waugh and Norton 1969; Gates 1974; Raizin and Regier 1986);
2. Market models, including behavioral equations for both supply and demand for either the exvessel, wholesale, or retail market level (Blomo et al. 1982; Hopkins et al. 1982; Thompson et al. 1984; Houston and Li 1989);
3. Multilevel market models that include behavioral equations for supply and demand at two or more market levels (Doll 1972; Adams et al. 1987; Wang and Kellogg 1988).

Several of the studies addressed price determination at the exvessel level where grading first occurs for many species. However, king crab is not graded by size until it is processed for sale in domestic wholesale markets. The primary domestic product form is a 20-lb. box of legs and claws, graded by species and size. Wholesale prices reflect the size and species differentiation. Analysis of price determination should include the species and size price differences, as well as substitutional relationships among the various product forms at both the wholesale and retail levels.

Unfortunately, the data necessary to accomplish such analysis are not published by either government or private information sources. Published data on weekly wholesale prices of king crab legs and claws are available from two sources: (NMFS) and Urner Barry Publications. Neither reports quantities sold, which is essential to price analysis.

NMFS periodically surveys several processors to estimate the wholesale price range for frozen king crab sections. Prior to November 1989, they published prices for only two king crab product forms: frozen sections and meat. This price series never discriminated by size-graded product nor by species, even though the wholesale market reflected such distinctions for more than a decade. Species and size distinctions became even more important when the industry collapsed in 1981. It was not until 1989 that NMFS began reporting price by species and pack count.

The Urner Barry Seafood Price Current (SPC) is an alternate source of wholesale price data for frozen king crab legs and claws by species and size. Because SPC uses different sources than NMFS, size classifications and prices reported are not always consistent. SPC classifies the largest red king crab legs as 8 to 12 legs and claws per 10 lbs., while NMFS classifies them as 9 to 12 count. Prices for the same species and size differed by up to $0.40 per pound in the November 1989 SPC and NMFS reports.

To gather more complete information about sales of king crab legs and claws in the U.S., major shore-based processors were asked to contribute data for this research. Data concerning individual sales and monthly inventories, May 1987 through December 1989, were gathered. Data from one processor who agreed to participate was not used because the financial relationship between that firm and its major customer may have influenced wholesale price. The remaining data represented about 40% of domestic king crab sales in the U.S. during 1988.

The data do not necessarily reflect general industry behavior, despite the large percentage representation. There are three main groups in the king crab processing industry not represented in the data: (1) smaller, shore-based and floating processors, (2) independent catcher-processors, and (3) one company that imports king crab from the Russian Far East. Initial contacts with firms in these categories revealed, in general, that they did not have a computerized, historical data series over the 1987–89 marketing years, or they were unwilling to cooperate. It is assumed that quantities traded each month by processors in the present sample are representative of industry behavior.

OVERVIEW OF THE KING CRAB INDUSTRY, PRODUCTS, AND MARKETS

King crab are harvested primarily in the United States, the Russian Far East, and South American countries. The U.S. domestic king crab market is supplied by Alaskan harvests, as well as product imported from Russia. Japan and Canada are the principal export markets for Alaskan king crab. This chapter describes supply sources, processing techniques, and distribution of king crab products to the U.S. and other world markets.

The World Market

Four species of shellfish are commonly referred to as king crab. Red king crab, blue king crab, *Paralithodes platypus*, and golden king crab inhabit the North Pacific, primarily off Alaska and the Russian Far East. Centolla or southern king crab, *Lithodes antarcticai,* is harvested off the coast of South America. Historically, red king crab were the staple of American and Russian king crab fisheries. Sharp declines in Alaska red king crab harvests between 1981 and 1983 and stock conditions that continue to be depressed today spurred development in other king crab fisheries. Blue king crab, harvested by Russians in the Bering Sea, and by Americans in the Pribilof and St. Matthew Islands, enjoyed a brief period of importance from 1981 to 1984. Harvests of this species have also declined in recent years. Golden king crab fisheries developed during the mid-1980s, following the collapse of the red king crab fisheries. Russian golden king crab were first imported to the U.S. in 1989.

Since the collapse of the Alaskan king crab fishery, Russia harvests more king crab than any other nation, followed by the U.S., Chile, Japan, and Korea (FAO 1990). Table 1 summarizes harvests of all king crab species by country and year.

Accurate statistics on international trade in king crab products are impossible to obtain because United Nations publications aggregate the various species of crab. Presumably, the Japanese consume most of their own domestic king crab harvest. They also import king crab from Russia. In recent years, Japan purchased the majority of Alaskan king crab. The U.S. imports king crab from the Russian Far East and South American countries and exports product to Japan, Canada, and Europe. South American countries export primarily to the U.S., but also have markets in South America, Japan, and Europe.

Red king crab is regarded the superior product, even though there is little difference in the taste or texture across species. Shell coloration and shell "in-fill" (i.e., the percent of the leg and claw shell volume that is full of meat) characteristics distinguish the species. Physical appearance of red and blue king crab are so similar that the two species often are combined and sold as red king crab. Both have red coloration on the top and are white on the bottom. Golden king crab have red coloring the full circumference of the shells and meat.

The more important market consideration concerning price differentials between red and golden crab relates to in-fill. Physiological differences between red and golden king crab create in-fill problems for golden king crab, but not for red king crab. Adult male king crab molt (shed their shells) synchroniously once a year during spring, whereas golden king crab molt several times a year. Timing of the relatively short red king crab fishery allows the crab to grow into their larger shell prior to harvest. The golden king crab fishery, however, operates year around. Crab caught shortly after molting do not have time to grow into their larger shell — meat does not fill the shell. In-fill problems contribute to lower golden king crab exvessel and wholesale prices.

The U.S. King Crab Industry

The U.S. king crab industry is made up of firms involved in the harvesting, processing, and selling of king crab products (Figure 1). They include commercial fishers, catcher-processors, primary seafood processors, secondary seafood processors, wholesale seafood distributors, seafood brokers, trader/converters, and retail firms. Each of these industry members perform a specific function in the processing and delivering a final product to consumers, and many firms perform more than one function. The functions can be categorized as harvesting, primary processing, secondary processing, and product distribution. Harvesting refers to capture and delivery of live king crab. Primary and secondary processing involve all activities, from the time king crab is delivered to a processor to the packaging of the final product. Product distribution is the function of industry members who provide the final product to consumers. King crab sold in the domestic market is distributed by processors themselves, their brokers, or by firms that purchase product from processors and resell it.

Harvesting

Domestic harvests of red, blue, and golden king crab occur primarily in the Bering Sea and Aleutian Islands of Alaska. King crab is harvested by either commercial fishers or by catcher-processor vessel operators. In the first case, harvesting and processing functions are performed by separate firms. The catcher-processor performs both functions at sea.

Crab harvested on commercial fishing vessels are sold live to seafood processing firms operating floating processor vessels or on-shore processing plants. Transactions at this level are termed "exvessel." Fishers are paid an exvessel price which differs by species only, with red king crab receiving the highest price. Exvessel price does not differ on the basis of quality or size of crab.

Processing

King crab processors are divided into three groups: large, vertically integrated firms; small independent processors; and catcher-processors. Many of the largest processing firms are subsidiaries of large U.S. or Japanese corporations. They process king crab at either shore-based plants, floating processing plants, or on catcher-processor vessels. These firms generally operate at least two of these plant types, and often all three. They are involved in processing many different types of seafood products, and have the capability to pack bulk (ungraded), raw or cooked king crab products raw or cooked into a variety of carton sizes in their Alaska plants. Smaller independent processing firms generally operate a single plant, handle fewer seafood products, and produce primarily bulk king crab. Independent catcher-processors harvest and process king crab on the same vessel.

There are two dominant levels of king crab processing — primary processing and secondary processing. Primary processing occurs in Alaska at either shore-based or floating processors or on-board a catcher-processor vessel. This initial processing of king crab is essentially the same in all three plant types and includes all activities necessary to produce bulk packaged frozen king crab clusters separated by species. A cluster is composed of one-half a cleaned crab with three walking legs, a claw, and shoulder meats. The bulk product is packaged in a variety of box sizes, including 10 kg (23.7 lbs), 25 lbs, 80 lbs, and 90 lbs, depending on plant capabilities and customer preference.

Although processing techniques do not differ among processor types, the catcher-processors usually have the capability to pack only bulk king crab into one size box and, therefore, frequently sell their products to other processors for secondary processing into the final form. Some sell directly to the Japanese, who buy primarily bulk-packed, raw frozen clusters. However, many catcher-processors do not appear to have well-established relationships with Japanese customers.

Crab processed as frozen clusters are butchered (split), gilled, and then either frozen raw for the Japanese market or cooked, cooled, brined, and frozen for the U.S. and Canadian markets. Raw frozen king crab is chemically treated prior to freezing to prevent discoloration. The maximum shelf life of both raw and cooked crab is approximately 2 years.

Bulk king crab clusters not exported directly from Alaska usually are shipped to Seattle for secondary processing which involves breaking down the bulk crab into final product forms and repackaging. The most important final product form is the 20-lb box of frozen king crab legs and claws, graded by size. Frozen clusters are broken apart, shoulder meats are trimmed, legs are separated into size groups, and the 20-lb boxes are packed with legs and claws in 3:1 proportion. Each box is identified by species and pack-count, i.e., the average number of legs per 10 lbs. For example, "Red 9/12" refers to a 20-lb box of red king crab containing from 9 to 12 crab legs and claws per 10 lbs, or 18 to 24 legs and claws per box. Other size categories include "12/14," "14/16," "16/20" (medium crab legs), "20/up" or "20/25" (small crab legs). This labeling convention began when 10-lb boxes were the industry standard, and has remained, although the standard box size is now 20 lbs.

Several other less important product forms are produced. These include individual legs or portions of a leg, split legs (individual leg is split down the middle), broiler claws, or other specialty products.

Alaskan King Crab Exports

Japan is the main export market for Alaskan king crab. The Japanese import primarily raw red king crab clusters, though they also purchase brine frozen, graded product. The majority of Japanese purchases are essentially "contracted" prior to the fall season. Preseason agreements on price, general quantities and product form allow processors to segment their processing facilities to satisfy Japanese product specifications. This kind of loose contracting is desirable for American processors because the majority of Japanese purchases are paid in cash within 2 weeks of initial processing and shipment. This generates substantial early season cash flow. It also avoids costly shipment to Seattle, reprocessing, and warehousing, and it lessens processor risk.

King Crab Imports

Red, blue, and golden king crab are imported to the U.S. from Russia primarily through a joint venture between a Kamchatka fishing cooperative and an American seafood processing firm.

However, Russian product also enters the U.S. through other countries. Prior to the break-up of the Soviet Union, Russian king crab was "blast frozen" rather than brine frozen like Alaskan king crab. This process resulted in a lower quality product. Russian king crab is imported as bulk clusters, reprocessed to various product forms in the U.S., and distributed to U.S., Canadian, and now Japanese markets. Wholesale price for king crab imported from Russia, historically, was less than the wholesale price for the same species and size of Alaskan king crab, though the price spread diminished as trade liberalization promoted rapid adoption of the U.S. brine freezing technology. Exact price differences are not reported by processors.

Although the imported king crab must be labeled a product of Russia, once it has undergone "significant" reprocessing in the U.S., this labeling is no longer required (Long 1990). The distinction between Russian and Alaskan king crab disappears at retail.

Unlike Russian king crab, centolla king crab imported from South America is not considered by the U.S. industry to be a competitor of North Pacific king crab species. This perception is largely a consequence of the U.S. Food and Drug Administration (FDA) regulations prohibiting labeling centolla as "king crab" (21 CFR 102.50). Nonetheless, some centolla enters the U.S. labeled as king crab, and it is advertised as such in industry trade magazines. Canned centolla used to be the primary product form, but recent FAO statistics list most sales of this product under the category "fresh/frozen" (FAO 1990), and FDA personnel report bulk boxes of frozen centolla legs and claws entering the U.S. through West Coast ports (Long 1990).

Distribution of King Crab in the U.S.

American processors distribute king crab to U.S. and Canadian markets by (1) selling directly to retail customers, (2) selling through brokers or wholesale food distributors, or (3) selling to other processors or to trader/converters. Brokers are agents of the processors and never take title of the king crab. They represent the processor in sales to wholesale or retail buyers, receiving a commission on sales. Although there is an additional cost for selling product through a broker, brokers are instrumental in selling other important seafood products such as surimi or salmon, which are sold in much more competitive markets. Allowing the brokers to also handle a high-valued product like king crab helps them promote the other products.

Wholesale food distributors purchase king crab from processors and sell it to restaurants or food markets. Food distributors generally supply these customers with a full line of food and food service products. Neither brokers nor wholesale food distributors perform any food processing functions. They only transfer product from processor to consumer without altering its form.

King crab also is sold to other processors and trader/converters. It may be resold in the same form or reprocessed into other product forms. Many catcher-processors sell their product through trader/converters because the catcher-processors often do not have the facilities to cut, grade, repackage the crab into 20-lb boxes of legs and claws, or to store the product. Although processors do purchase king crab products from one another, it is not a common practice because products sold to another processor become competing products on the wholesale market. Trader/converters have a unique niche in the market channel. They are closer to final consumption than processors, and thus, take advantage of knowledge about final demand and product availability. Their customers usually do not have an established relationship with a processing firm, or for some other reason, are not making regular purchases through the broker or food distributor network. Trader/converters purchase a particular king crab product from a primary or secondary processor, repackage or alter the product form, and then, resell it. They do not offer the full range of food product services as do the wholesale food distributors.

ANALYTICAL FRAMEWORK AND RESULTS

Theoretical Model

Wholesale prices and quantities for king crab products graded by size are determined simultaneously by buyers and sellers in the wholesale market. The conceptual model presented in equations (1)–(3) specifies important economic relationships in price and quantity formation.

$$Q^d_{ijt} = f(P_{ij}, P_{sub}, I, Z^d, e^d_{ij}) \tag{1}$$

$$Q^s_{ijt} = f(P_{ij}, C, TS_{ij}, Z^s, e^s_{ij}) \tag{2}$$

$$Q^d_{ijt} \equiv Q^s_{ij} = Q_{ij} \tag{3}$$

where:

i = product size (9/12, 12/14, 14/16, 16/20/ 20/25, 25/up);

j = species (R for red and G for golden);

t = month;

Q^d_{ijk} = quantity of size class i and king crab species j demanded by wholesale buyers in month t;

Q^s_{ijt} = quantity of size class i and species j supplied by processors in month t;

P_{ijt} = wholesale price per pound for size class i and species j of king crab in month t;

P_{subt} = wholesale price per pound for substitute products including other species and sizes of king crab and other seafood products;

I_t = monthly consumer income;

C_t = processor's costs of production and storage for king crab graded by species and size in month t;

TS_{ijt} = total available supply for size class i and the species j of red king crab at the beginning of month t;

Z_t^d = other variables influencing retail and wholesale demand for king crab;

Z_t^s = other variables influencing wholesale supply of king crab;

e_{ijt} = error term for demand (d) and supply (s) equations.

The specification of five size categories for both species of king crab results in a structural model containing 30 equations, three equations for each species and size class. There are 20 behavioral equations and 10 identities.

Equation (1) represents demand functions, where the quantity of each size and species of king crab legs demanded by wholesale buyers is determined by the price of that product (own price), price of substitutes, consumer income, other variables influencing retail and wholesale demand for king crab products (Z^d), and a random error term.

The wholesale demand for king crab is a "derived demand," meaning that it is derived from the primary demand at the retail level. One important variable that influences both wholesale and retail demand is the type of retail market. Demand for king crab may differ depending on whether it will be sold at a seafood market, a midrange restaurant, or a white tablecloth restaurant. For example, people buying king crab at seafood markets may prefer a different size or species than those eating at white tablecloth restaurants. Another important characteristic of wholesale demand, which may influence prices and quantities, is the relationship between the wholesale buyer and seller. Large volume buyers, or those with long-term relationships with the processors, undoubtedly are able to obtain product at more favorable terms than buyers who purchase small volumes or do not have an established relationship with the processor.

Equation (2) represents the quantity of various sizes of red and golden king crab supplied to the wholesale market by seafood processors. Quantity supplied is a function of own price, costs of production, the total available supply of both red and golden king crab throughout the marketing year, other factors which influence the supply of king crab (Z^s), and a random error term.

Equation (3) represents the market-clearing identity. It requires the quantity supplied of a particular product equal the quantity demanded each month. The sets of supply and demand equations for each product form are related because consumers conceivably consider different sizes and species of king crab as possible substitutes for each other. Adjacent sizes of the same species are probably substitutes. Therefore, prices of some substitute sizes and species of king crab appear as explanatory variables in each equation. For example, Red 12/14 and 16/20 presumably substitute for Red 14/16. Some sizes of the less valuable golden king crab may also substitute for red king crab, particularly in the smaller red size classes.

In the structural model specified in equations (1)–(3), quantities and prices of the different species and size classes are endogenous, i.e., their values are simultaneously determined within the system of equations. Other variables specified in the model, such as income, price of non-king crab substitutes, and processor costs, are exogenous variables. Their values are determined outside the model. There are 20 endogenous variables and 13 exogenous variables specified in this system. Any additional variables considered as Z^d or Z^s variables are also exogenous.

Simultaneity means that any factor which causes a change in prices will lead to a simultaneous change in quantities. As a result, error terms in each demand and each supply equation are correlated with explanatory variables. Thus, ordinary least squares (OLS) estimates of these parameters are both biased and inconsistent (Judge et al. 1988).

Simultaneous equations estimation procedures account for this simultaneity between dependent and explanatory variables by using information from exogenous variables to generate the parameter estimates. These "instrumental" variables must be uncorrelated with the error term but correlated with the explanatory variables (Maddala 1988).

Two-stage least squares (2SLS), the most common simultaneous equation estimation technique, involves expressing the structural equations in reduced form, i.e., each endogenous variable is a function of all exogenous variables. In the structural model specified above, there are 20 equations in the reduced form, 10 wholesale price equations, and 10 quantity equations. Each equation expresses price or quantity of a species and size of king crab as a function of prices of exogenous substitute goods (not other king crab products), income, processor costs, total available supply of five red king crab sizes and five golden king crab sizes, and any other variables identified by Z^d and Z^s.

In the first stage of 2SLS, each reduced form equation is estimated using OLS. In the second stage, right-hand side endogenous variables are replaced by their predicted values from stage one. In particular, the estimated prices from the first stage become instruments which replace original right-hand side prices in estimation of the structural equations.

To use 2SLS, OLS estimates of the reduced form equations must generate acceptable predicted values of the endogenous variables to replace in the original structural equations. However, OLS estimates of the reduced form equations resulted in equations with poor fit, as evidenced by low t statistics and signs inconsistent with economic theory.

Two potential data problems may have contributed to these results. First, there were not enough exogenous variables included in the model. Specifically, observations on important characteristics of retail and wholesale demand for various sizes and species of king crab were not available. A second problem relates to measurement error in the quantity variables. As mentioned in earlier, sales data were collected from processors that represented 40% of domestic sales in 1988. The reduced form equations were estimated using only a portion of the actual quantities sold, causing the coefficient estimates in the reduced form equations to be biased toward zero. This bias may also have contributed to the low t values.

Due to the difficulty in constructing adequate instruments, no further attempt was made to estimate these equations with a simultaneous systems method. Alternative methods were developed based on both published data and information collected from processors. This data, and the limitations that resulted from it, are described in the following section. Alternative model specification follow the data section.

Data

Data collected from participating processors included date of sale, product form (including species and size), pounds sold, wholesale price per pound, transportation cost per pound, location where title of product transferred, other price adjustments per pound, and a customer identification number. Originally, processors were asked to identify all buyers so specific buyer characteristics, such as the relationship between buyer and seller and the type of retail market, could be identified. One processor, however, declined to provide this information, which meant that no information about buyers could be used in this study.

Complete data on sales by all contributing firms were available from May 1987 through December 1989 (32 months). Only domestic sales of king crab legs and claws graded by species and size and packed into 20-lb boxes were used. Sales to customers in Canada, Japan, or Europe were excluded from the data set. Finally, king crab legs and claws that sold for less than $3.00 per pound were presumed to be of inferior quality, considered outliers, and excluded from the data set.

Wholesale price was adjusted for each sale to an FOB Seattle price by subtracting broker fees and transportation costs. In some cases, actual transportation costs for each sale were provided by the processor; however, a significant number of prices were adjusted by applying an estimated transportation cost from Seattle to the customer's general geographic area of the United States.

Pack count categories were found to differ slightly among processors. Based on advice from industry members, a standardized pack count classification was imposed on the data set. Legs and claws were divided into 12 species/size categories. The name of the product form, which specifies both species and size, as well as the name of the wholesale price variables, are listed in Table 2. For example, PR9/12 refers to the price per pound of Red 9/12 legs and claws.

Some size classes were combined for each species. The categories Red 14/16 and Gold 14/16 includes sales of both 14/16 count and 14/17 count product. Similarly, Red 20/25 includes sales of 20/24, 20/25, and 21/24. Gold 20/25 includes sales of 20/24, 20/25, and 21/24. Gold 20/up includes sales of 20/up, 24/up, and 25/30. Red 20/up and Gold 9/12 were not considered in this analysis because of the extremely limited sales volume.

Individual sales were aggregated to a monthly basis because insufficient observations existed to estimate a model based on daily sales. Monthly aggregation also protects the confidentiality of processors who contributed data. A monthly average wholesale price, weighted by pounds sold, was calculated for each species and size category.

Red King Crab Wholesale Prices

Monthly weighted average domestic wholesale price for five sizes of red king crab are presented in Figure 2. During the 1987–88 season, red king crab prices ranged from $7.19/lb. for small legs to $10.90/lb. for large legs. Price spreads between the adjacent size groups ranged from about $0.30 to $0.65/lb. between Red 9/12 and 12/14; from $0.20 to $0.80/lb. between Red 12/14 and 14/16, and between 14/16 and 16/20; and from $0.75 to $0.45 between Red 16/20 and 20/25. The spreads were much more variable over time between smaller sizes than between larger sizes.

Price inversions (negative price spreads) occurred between the four largest size groups during September, October, and November 1988. In September 1988, Red 14/16 was selling for $0.13/lb. more than the larger sized 12/14. This "price inversion" also occurred in three other size categories. All inversions occurred at the end of a marketing year, suggesting that processors may discount the previous season's product in an attempt to sell it before newer product is processed.

Harvest declined from approximately 13.6 million pounds in 1987–88 to 8.8 million pounds in the 1988–89 season. This decline in catch is, in part, responsible for the 20% rise in average exvessel price ($4.10 to $5.08). Wholesale prices for red king crab were also higher during the 1988–89 season, ranging from approximately $9.00/lb. to about $12.75 per pound, but price spreads between sizes were much narrower, particularly with the larger crab. Monthly price variability within size category increased in comparison to the previous season for most sizes of red king crab.

Golden King Crab Wholesale Prices

Monthly weighted average domestic wholesale prices for golden king crab legs and claws are presented in Figure 3. Wholesale prices in 1988 ranged from about $6.00/lb. for the smallest size category to over $10.00/lb. for Gold 12/14. In 1989, wholesale prices for the same products ranged from about $7.50/ lb. to over $11.50/lb. Price spreads between sizes in 1989 were generally larger and more variable than those in 1988.

Price spreads between the same sizes of red and golden king crab legs and claws varied by pack count and time. In general, however, the cross-species price spreads were smaller and less variable during the 1987–88 red king crab fishing year. For example, the price difference between Red 12/14 and Gold 12/14 ranged from -$0.10 to $0.70/ lb. from October 1987 through August 1988. The price spread widened to about $1.00 in September 1988, and then was steady at $2.00/lb. for the remainder of 1988. It fluctuated between $0.50 and $2.40/lb. during the next year. A similar pattern in the differences between the prices of Red 14/16 and Gold 14/16 occurred. In the smaller sizes, 16/20 and 20/25, price spreads fluctuated between $0.40 and $1.40/ lb. during the 1987–88 season, and were as high as $2.20 and $2.00/lb. during 1988–89.

Inventory

Inventory (INV) measures the available supply of king crab products. It is assumed to be inversely related to price. As available supply decreases, and the influence of other factors are held constant, prices are expected to increase. Developing an accurate estimate of available supplies by species and size was problematic. Beginning-of-month inventory figures provided by processors did not reflect the true availability of king crab product throughout the year.

During a given month, processors can produce more product by reprocessing bulk king crab into graded product, or by purchasing graded product from other processors. It is not uncommon for sales of a particular species and size to occur in a month when beginning inventories were zero, or for pounds sold to be greater than beginning inventory. Thus, beginning-of-month inventory figures supplied by the processors were not used in this analysis.

Instead, total available supplies of red king crab graded by size were computed based on cumulative annual sales of the processors surveyed less their monthly sales (QS_{it}). This measure of supply is presumed to be known before the marketing season because processors know total catch, exports to Japan, and the general size distribution of bulk processed crab. The inventory variable in October of each year was set equal to total seasonal year sales of the particular size class. Beginning stocks in successive months were calculated by subtracting monthly sales from the prior month inventory.

No such available supply measure could be compiled for golden king crab because they are managed without a quota or harvest guideline range and harvests occur during each month of the year. Processors have very limited ability to predict the amount or size distribution of golden king crab. Inability to construct a measure of total available supply of golden king crab means that a critical variable in modeling price determination is missing. For this reason, the analysis had to be limited to the study of red king crab pricing.

Exvessel Price

Increases in exvessel price should increase wholesale price because it is the major component of processors' costs (Greenberg 1990; Matulich et al. 1990). Because the Alaska red king crab season now is limited to not more than a few weeks each fall, seasonal average exvessel price for red king crab (PEXR) took on only two values through the period studied: $4.00/lb. in 1987–88, and $5.08/lb. in 1988–89.

Lobster Wholesale Prices

Lobster often is considered a high-valued substitute for king crab. The wholesale price of king crab and the wholesale price of lobster are assumed to be positively related. As the price of lobster increases, consumers should increase their demand for relatively less expensive king crab. This ultimately results in an increase in the wholesale price for king crab. Two alternative lobster prices were considered in this analysis: the monthly average wholesale price per pound for fresh, 2-lb.

Maine lobsters (PLOBM), and the monthly average wholesale price per pound for 8–10 ounce Australian lobster tails (PLOBA). Appendix A contains more detail on how these prices were calculated and Appendix B lists monthly prices for the study period. Previous modeling of king crab markets gave no indication that other seafood, meat, or poultry products were substitutes for king crab (Greenberg 1990; Hanson 1987).

Consumer Income

Changes in consumer income affect the retail demand and price for king crab. As income increases, demand for king crab should increase, thereby increasing prices per pound at all market levels. Both income and expenditure measures may be used to quantify the effect of income changes on wholesale prices. Monthly per capita disposable personal and per capita expenditures in restaurants, lunchrooms, and cafeterias were both considered in this analysis.

Summary of Available Data

Thirty-two monthly observations on wholesale prices for five sizes of red and golden king crab legs and claws are available. Inability to estimate golden king crab supplies restricted the analysis to modeling only red king crab price formation. Only 24 of the observations on red king crab prices are used because calculation of the inventory variable required data on complete marketing years. Exvessel price for Red king crab (PEXR) measures a major component of processor's costs. The wholesale price of Australian rock lobster tails (PLOBA) and 2-lb. live Maine lobsters (PLOBM) measure the effect of changes in the price of substitute seafood products. Per capita expenditures in restaurants (PCREST) measures the effect of changes in consumer income on the demand for king crab. King crab wholesale prices are simultaneously determined endogenous variables. Exvessel prices of king crab, prices of lobster, and expenditures in restaurants are considered exogenous in this model. Appendix A contains more detailed descriptions of methods used to calculate variables, data sources, and units of measurement. Appendix B contains tables reporting monthly values for all variables included in the final model. Prices are not adjusted for inflation.

Measures of other characteristics such as the type of retail market, and the relationship between wholesale buyers and sellers could not be obtained. Lack of information about demand characteristics is a critical deficiency in the data set. It prevents estimation of the structural model because observations on a sufficient number of exogenous variables are not available to construct good instrumental variables. Alternate feasible estimation procedures, in light of available data, are discussed in the following section.

Empirical Extensions to the Conceptual Model

Given the available data, an alternate reduced form specification, which expressed price for each size of red king crab legs and claws as a function of only exogenous variables, was estimated using the inventory variables (INV_{it}) to approximate total available supply. The most general form of this reduced form is

$$\begin{aligned} PR_{it} = {} & \beta_{i1}\, PEXR_t + \beta_{i2}\, INV9/12_t + \beta_{i3}\, INV12/14_t \\ & + \beta_{i4}\, INV14/16_t + \beta_{i5}\, INV16/20_t + \beta_{i6}\, INV20/25_t \qquad \textbf{(4)} \\ & + \beta_{i7}\, PLOBA_t + \beta_{i8}\, PCREST_t \end{aligned}$$

where: t = month

Equation (4) was estimated using OLS for the five different sizes of red king crab. However, the results of this estimation were not satisfactory, in large part because all size-graded products are interdependent. This, coupled with the short 2-year time series, contributed to a high degree of multicolinearity among inventory variables. Low t values and numerous incorrect signs plagued the specification.

A second alternative model specification that can be derived from the structural model in equations (1)–(3), but that fails to address the problem of simultaneity, is a "partial reduced form" in which some endogenous variables remain as explanatory variables. Equation (5) is a general form of five equations which express wholesale price of red king crab legs and claws as a function of exvessel prices, the price of a lobster substitute, own inventory, prices of adjacent sizes of red king crab legs and claws, and the price of the next larger golden crab size category. It is a partial reduced form because prices of other sizes of red king crab are used to capture the effects of substitute sizes of red king crab, i.e.,

$$\begin{aligned} PR_{it} = {} & \beta_{i1}\, PEXR_t + \beta_{i2}\, PR_{i-1,t} + \beta_{i3}\, PR_{i+1,t} \\ & + \beta_{i4}\, PG_{i-1,t} + \beta_{i5}\, INV_{it} + \beta_{i6}\, PLOBA_t \qquad \textbf{(5)} \\ & + \beta_{i7}\, PCREST_t \end{aligned}$$

where: i = 9/12, 12/14, 14/16, 16/20, 20/25
$i-1$ = larger size red king crab
$i+1$ = smaller size red king crab
t = month

This "compromise" specification is an empirical necessity due to limited data.

The presence of red king crab prices as explanatory variables leads to the problem of simultaneous equation bias. Inadequate observation of sufficient exogenous variables to use a simultaneous equation method required the use of OLS. The use of OLS is supported by Kennedy (1989) in the context of small samples.

Equation (5) was estimated without an intercept so that the coefficient on exvessel price, which is one value per season, could be interpreted as the margin of wholesale price over exvessel price. Including an intercept would result in exvessel price acting only as an indicator variable for the marketing year. The data used to estimate these equations are listed in Appendix B.

The ultimate estimation of equation (5) involved three other considerations. First, the September 1989 observation was dropped from the data set. As can be seen in Figure 4, wholesale prices generally trend upward throughout each year. In September, processors are trying to sell current year stocks before the next season, so prices may drop to facilitate end of year sales. Although harvest levels and exvessel price remained essentially the same from the 1988–89 season to the 1989–90 season, some factor, possibly related to expectations next season, was not included in our model, but was influencing wholesale prices downward at the end of the 1988–89 marketing year. Prices were declining with shrinking stocks, contrary to expectations about the relationship between price and available quantity. This behavior resulted in large residuals in the Red 12/14 and Red 20/25 estimated models.

A dummy variable containing zeros in all months except September 1989 was used to test whether these observations were outliers. Based on a t-test, coefficients on the dummy variables were significant at the 99% level, so the observations were dropped from the data set. Estimates for the other size classes were not affected so dramatically by this final observation. However, PR12/14 and PR20/25 are included in adjacent equations requiring that the final observation be dropped for all equations.

The second consideration ultimately involved dropping an income measure from equation (5). Per capita expenditure at restaurants was included in original estimations because this variable was not significant in these models. This result is not surprising because it is unlikely that consumer income would change enough in 2 years to significantly impact wholesale prices.

The third consideration involved dropping golden crab as a substitute for red crab. Initially, the equations were estimated with the price of both red and golden substitute sizes as explanatory variables. However, high correlation between price variables forced exclusion of the gold prices, and no inventory variable for golden crab could be constructed.

The final results of OLS estimation of equation (5) are given in (6)-(10) below; t-values associated with the parameter estimates are reported in parenthesis.

$$PR9/12 = \underset{(0.885)}{0.5853\ PEXR} + \underset{(1.536)}{0.5369\ PR12/14} - \underset{(-0.697)}{0.0049\ INV9/12} + \underset{(2.395)}{0.1892\ PLOBA} \qquad (6)$$

$$R^2 = 0.9995 \qquad F = 7{,}900$$

$$PR12/14 = \underset{(2.691)}{1.0569\ PEXR} + \underset{(0.731)}{0.1135\ PR9/12} + \underset{(1.820)}{0.3773\ PR14/16} - \underset{(-1.259)}{0.0009\ INV12/14} \qquad (7)$$

$$+ \underset{(1.790)}{0.0732\ PLOBA}$$

$R^2 = 0.9998 \quad F = 15{,}656$

$$\begin{array}{lllll} \mathrm{PR14/16} = & 0.5513\ \mathrm{PEXR} & + 0.4728\ \mathrm{PR12/14} & + 0.2921\ \mathrm{PR16/20} & - 0.0007\ \mathrm{INV14/16} \\ & (1.928) & (2.532) & (1.619) & (-1.976) \end{array} \qquad \mathbf{(8)}$$

$R^2 = 0.9997 \quad F = 18{,}483$

$$\begin{array}{lllll} \mathrm{PR16/20} = & 0.9735\ \mathrm{PEXR} & + 0.3764\ \mathrm{PR14/16} & + 0.0343\ \mathrm{PR20/25} & - 0.0019\ \mathrm{INV16/20} \\ & (2.505) & (2.362) & (0.290) & (-2.548) \\ & + 0.0886\ \mathrm{PLOBA} & & & \\ & (4.219) & & & \end{array} \qquad \mathbf{(9)}$$

$R^2 = 0.9998 \quad F = 15{,}179$

$$\begin{array}{lllll} \mathrm{PR20/25} = & 1.0465\ \mathrm{PEXR} & + 0.2751\ \mathrm{PR16/20} & - 0.0213\ \mathrm{INV20/25} & + 0.1369\ \mathrm{PLOBA} \\ & (2.647) & (1.212) & (-4.634) & (2.842) \end{array} \qquad \mathbf{(10)}$$

$R^2 = 0.9993 \quad F = 7{,}020$

The signs on all coefficient estimates are consistent with economic theory. An increase in exvessel price leads to an increase in wholesale price. Prices of substitute sizes of king crab and Australian rock lobster tails are positively related to king crab prices. Maine lobster is not a staticly significant substitute. As the price of substitutes increase, demand for the size of king crab in question increases as buyers substitute away from the relatively more expensive substitute. As demand increases in response to an increase in the price of a substitute, own price increases. Finally, stocks are inversely related to price. As the amount of product in inventory declines, price increases. The coefficient of determination (R^2) measures the proportion of total variation in the dependent variable that is explained by the set of explanatory variables. These coefficients have been adjusted, through the SAS regression procedure, for estimation without an intercept term. The high explanatory power of these models, as evidenced by R^2s very close to 1.0, is, in part, a feature of using time series data and estimating a model with highly correlated explanatory variables that are also highly correlated with the dependent variable. Both the dependent and explanatory variables reflect similar time trends.

The overall significance of a multiple regression equation is determined by testing the hypothesis that all coefficient estimates are equal to zero against the hypothesis that not all coefficient estimates are equal to zero. The calculated F statistics for equations (6)–(10) leads to the conclusion that not all the coefficient estimates are equal to zero at the 95% level. Similarly, one-tailed t-tests suggest that all but four coefficient estimates in these equations are significant at the 90% level. Variables not significant at the 90% level include exvessel price and inventory in equation (6), PR9/12 in equation (7), and PR20/25 in equation (9).

Bayesian Bootstrap Estimates

Two features of the OLS estimation motivated use of Bayesian bootstrapping with informative priors to obtain better estimates for subsequent analysis. First, the OLS parameter estimates are based upon a small sample of 23 monthly observations. Second, while the OLS parameter estimates revealed signs consistent with economic theory, use of sign restrictions as prior information and Monte Carlo sampling (bootstrapping) will yield parameter estimates that are more efficient in the sense of minimizing expected quadratic loss in parameter estimation. In particular, use of prior information in conjunction with the observed data yields "best guess" or "optimal" parameter estimates in a Bayesian context.

The Bayesian estimates were obtained by bootstrap sampling using minimally restrictive prior information, i.e., that all substitute prices are positively signed, exvessel price is positively signed, and available supplies (stocks) are negatively signed. Ten thousand samples were bootstrapped using the Bayesian inequality constrained estimation (Geweke 1986) algorithm (Shazam Version 6.1, 1990).

Unlike OLS, Bayesian estimates are not evaluated in terms of their sampling properties. Classical hypothesis test statistics, including t-statistics, and F-statistics can no longer be used to test hypotheses because the repeated sampling context of these test procedures are no longer valid. Instead, Bayesian point estimates are interpreted as the best that can be obtained, given the prior and sample information and the particular loss function (i.e., quadratic loss). The numerical standard errors of these parameter estimates indicate how precisely the parameter estimates represent the mean of the posterior distribution. A desirable outcome of the bootstrapping process is that it provides an estimate of the probability that the *a priori* restrictions hold. That is, one can evaluate the consistency of the restrictions with the observed data within the context of the model specified.

The bootstrap estimates are provided below in equations (11)–(15); numerical standard errors are in parenthesis.

$$\begin{array}{lllll} \text{PR9/12} = & 0.7661\ \text{PEXR} & +\ 0.4302\ \text{PR12/14} & -\ 0.0077\ \text{INV9/12} & +\ 0.2165\ \text{PLOBA} \\ & (0.0054) & (0.0028) & (0.650\text{E-}4) & (0.0007) \end{array} \qquad \mathbf{(11)}$$

58.31% of replications satisfied constraints

$$\begin{array}{lllll} \text{PR1/142} = & 1.0365\ \text{PEXR} & +\ 0.1677\ \text{PR9/12} & +\ 0.3396\ \text{PR14/16} & -\ 0.0010\ \text{INV12/14} \\ & (0.0042) & (0.0014) & (0.0021) & (0.739\text{E-}5) \end{array} \qquad \mathbf{(12)}$$

$$\begin{array}{l} +\ 0.0657\ \text{PLOBA} \\ (0.0004) \end{array}$$

63.47% of replications satisfied constraints

$$\begin{array}{lllll} PR14/16 = & 0.5689\ PEXR & + 0.4521\ PR12/14 & + 0.3075\ PR16/20 & - 0.0007\ INV14/16 \\ & (0.0029) & (0.0018) & (0.0021) & (0.377E\text{-}5) \end{array} \tag{13}$$

86.64% of replications satisfied constraints

$$\begin{array}{lllll} PR16/20 = & 0.8617\ PEXR & + 0.3654\ PR14/16 & + 0.1087\ PR20/25 & - 0.0016\ INV16/20 \\ & (0.0044) & (0.0020) & (0.1047) & (0.846E\text{-}5) \\ & + 0.0841\ PLOBA & & & \\ & (0.0002) & & & \end{array} \tag{14}$$

58.95% of replications satisfied constraints

$$\begin{array}{lllll} PR20/25 = & 0.9692\ PEXR & + 0.3206\ PR16/20 & - 0.0208\ INV20/25 & + 0.1298\ PLOBA \\ & (0.0035) & (0.1976) & (0.478E\text{-}4) & (0.0005) \end{array} \tag{15}$$

87.14% of replications satisfied constraints

Coefficient estimates from the Bayesian procedures are of similar magnitude as those from the OLS estimates in (6)–(10), with one exception. The estimate on PR20/25 in equation (14) is three times that of the OLS coefficient estimate in equation (9). The probability that the sign restrictions are satisfied within the context of the specified model ranges from 58% to 87%. The bootstrap parameter estimates are used for subsequent analysis of red king crab prices.

Calculating Reduced form Multipliers

Conventional single-equation econometric analysis permits direct interpretation of the parameter estimates. However, because all five equations (11–15) are linked through the use of endogenous, explanatory variables, it is necessary to remove this cross-equation influence. That is, it is necessary to capture not only the direct effect of a change in an exogenous variable in a specific equation, but also the indirect effect as that change filters through the system of equations.

The reduced form of equations (11)–(15) expresses price for each size category as a function of only exogenous variables. Coefficient estimates from the reduced form equations are calculated by postmultiplying the inverse of a 5x5 matrix having ones on the diagonal and the negatives of the coefficient estimates on endogenous variables (price) on the off-diagonal, by the 5 x 7 matrix of coefficient estimates on exogenous variables. This procedure is shown in equation (16).

$$R = A^{-1}B \tag{16}$$

where:

R = 5 x 5 matrix of reduced form coefficients,
A^{-1} = 5 x 5 inverse matrix involving coefficients on endogenous variables, PR9/12 - PR20/25, and
B = 5 x 7 matrix of coefficients on exogenous variables.

The reduced form coefficients are impact multipliers which quantify the effect of a one unit change in an exogenous variable on prices given the relationships between all variables in the five equation model. Table 3 contains the reduced form multiplier matrix, R.

The reduced form multipliers indicate that processors operate ostensibly on a cost-plus pricing basis, where the parameter estimate on exvessel price times the value of exvessel price sets the margin for wholesale price over exvessel price. This conclusion is consistent with Greenberg (1990). From 1987–89, this margin was approximately 1.5 to 2.0 times input costs, as measured by exvessel price. The greatest margins occur with the 14/16 and 12/14 pack counts. Once the cost-plus base for wholesale price is determined, prices are adjusted by remaining inventories and the price of lobster tail substitute. Inventory is measured in 1,000 lbs. Small negative multipliers on INV9/12 through INV20/25 indicate that changes in stock levels has only very minor impact on general price level. Lobster prices, however, have a relatively important influence on the wholesale price of king crab in this model. A $1.00 increase in the price of lobster at the sample mean values yields from $0.11/lb. to $0.28/lb. increase in the price of red king crab.

HISTORICAL SIMULATIONS

Simulation enables one to validate a model *vis-à-vis* its ability to reproduce historical values of the endogenous variables over the estimation period. Simulation also enables one to forecast and to address policy questions by imposing different assumptions on exogenous variables.

Following an ex-post simulation to evaluate how well the estimated model reproduced historical prices over the 1987–89 time period, three policy simulations were conducted. The policy simulations were designed to offer a preliminary assessment of how a lower size limit might have affected wholesale prices and thus processors' revenue during the 1987–88 and 1988–89 marketing years. Implications also are drawn with regard to likely changes in exvessel price and revenue.

Simulation of the 1987–89 Estimation Period

Simulation of the historical data is accomplished by using the reduced form coefficient matrix in Table 3 and the values of exogenous variables in the original data set. Actual prices from the 1987–88 and 1988–89 marketing years and predicted values from simulation are compared in Figures 5 through 9. Two goodness-of-fit statistics confirm that, in general, the model simulates the historical data very well. The mean absolute percentage error (MA%E) is calculated by summing the individual absolute percentage errors (residual as a percentage of actual price) and dividing by the number of observations. The range of absolute percentage error and mean absolute percentage errors for the simulation of historical data are presented in Table 4. MA%Es are very low — less than 2.2% in all cases. The maximum error for a single observation is only 9% (Red 20/25).

A second simulation statistic, Theil's inequality coefficient (U), scales the root mean square simulation error (deviation of predicted value from actual value) so that the value of U is between 0 and 1 (Pindyck and Rubinfeld 1981). An inequality coefficient of zero indicates a perfect forecast. Table 5 presents values for this statistic and its decomposition into sources of simulation error. The bias proportion (U^M) measures systematic error or the average deviation between simulated and actual data. The regression proportion (U^R) also measures systematic error by evaluating the slope coefficient from a regression of changes in actual values on changes in predicted values. U^R increases as the slope coefficient differs from 1.0. Both U^M and U^R should be close to zero. The disturbance proportion, U^D measures the unsystematic proportion of forecast error attributable to random disturbances. U^D will be close to 1.0 if the other two sources of error are near zero.

The inequality coefficients for these simulations are near zero, so the model performs well in predicting actual prices. Both the bias and regression proportions are < 1%, indicating that the majority of forecast error is due to random disturbances and not systematic error in the estimation.

Simulating the Consequences of a Reduced Size Limit

Any consideration of a reduced size limit implies a new, smaller grade. However, there is no way to predict prices and sales of smaller crab. Nor is there any statistical way to estimate how a new, smaller grade will affect the substitutional relationships across the larger grades. Accordingly, this analysis simulates the influence of a size limit reduction by increasing the available supply of the smallest current size category (20/25 count). This increase in supply of 20/25s is achieved under three different policy scenarios, each reflecting alternative ways that a size limit policy change might be achieved. The economic consequences of the policy change is evaluated by comparing the resulting predicted prices and thus industry revenues with those of an historical baseline.

The historical baseline uses the multiplier matrix in Table 3 to hindcast monthly prices-by-size, assuming actual historical monthly inventories, exvessel prices and lobster prices. Cumulative industry revenues measured in October 1989 dollars, are then calculated. Predicted revenues to processors during the estimation period were calculated by compounding monthly revenues by the average prime interest rate on short-term loans over a 24-month period (9.91%). Total revenues reflect only the portion of the industry represented by the survey participants.

The first two reduced size-limit scenarios predict prices and revenues assuming quantities sold are identical to 1987–88 and 1988–89 levels. These represent policies of reducing the size limit while holding total annual harvest constant. The distribution of product is adjusted so that 20/25s represent 10% of total annual quantities sold in each year instead of 6.1% and 5.7%, respectively. Table 6 presents the actual total pounds sold and distribution by size. Scenario 1 assumes a uniform impact on harvest. Redistribution of total harvest is achieved by subtracting an equal percentage amount from the four larger pack counts (0.958% in the first year and 0.954% in the second year). Scenario 2 assumes the reduced size limit will have a disproportionate impact on the larger sizes. This possibility was modeled by reducing each of the four larger size categories be the same total poundage, i.e., 25% of the increase in 20/25 count quantity sold is removed from each of the four larger pack counts. Scenario 3 also assumes catch and thus quantities sold of 20/25s increase to 10% of total annual quantity sold. However, Scenario 3 treats this increase as a net addition to total quantity sold. It follows that this scenario represents a management policy of enlarging total harvest.

Predicted Prices

Predicted monthly prices-by-size are enumerated in Appendix B for the historical baseline and three alternative policy scenarios. Weighted average annual prices are summarized in Table 7. These results show that a reduced size limit policy has the greatest impact on price of the smallest crab. Average prices of 20/25s dropped $0.50/lb. in the first year and $0.37/lb. in the second year due to the increased sales. Price of the adjacent pack count (16/20s) dropped $0.06–$0.08/lb. the first year, but only $0.02–$0.03/lb. the second year. Differences in magnitudes between years is a consequence of cumulative quantity sold. Thirty-three percent more crab were sold in the 1987–88 marketing year. The particular policy scenario had little effect on the level of price changes. A notable exception relates to the price of 9/12s under Scenario 2. Price increased $0.04–$0.06/lb. This equal quantity scenario reflects a considerably reduced harvest of the largest crab. The large percentage reduction in the first-year volume sold of 9/12 count crab more than offset any weak substitution effects that trickle down from the much less expensive 20/25 count crab.

Predicted Revenues

Total revenues (October 1989 dollars) generated under each scenario are listed in Table 8. These revenue predictions portray a partial image of how industry well-being is likely to be affected by a reduced size-limit policy. It is immediately apparent that unlike prices, processing revenues depend upon the way in which a size limit reduction is achieved. Revenues are shown to rise slightly under Scenario 1, drop under Scenario 2, and rise under Scenario 3. Revenues rise from $18.31 million to $18.46 million when total harvest is held constant and the size distribution is changed in a constant percentage — Scenario 1. Only the 20/25 count revenues rise despite the $0.37–$0.50/lb. price drop. The 10% increase in quantity sold of 20/25s exceeded the 4%–6% price decrease.

Total revenues fall from $18.30 million to $18.09 million when the redistribution involves a constant quantity reduction (harvest) by size — Scenario 2. Changes in individual pack count revenues follow a pattern similar to Scenario 1. Even the 9/12 revenues drop despite the $0.04–$0.06/lb. average price rise. This result is a consequence of the relatively small percentage increase in price being more than offset by the larger percentage decline in quantity sold.

When total harvest is allowed to expand in order to increase the supply of 20/25s, revenue raises from $18.30 million to $18.61 million. Even though total sales volume expanded < 5%, and only in the smallest size category, the effect rippled up grade. The adjacent larger size (16/20) revenues dropped more than a quarter of a million dollars.

Simulation of 1989–90 Wholesale Prices

Forecasting wholesale prices in the 1989–90 marketing year, one year beyond the data, reveals that the model is not sufficiently robust to use in general forecasting. This is not surprising given that the model was developed with only 2 years of observations, and then, without the ability to properly specify a theoretically correct model.

Forecasting the 1989–90 prices with the estimated model simply requires that data for exogenous variables be specified. The predicted price in any month is the product of the reduced form multipliers from Table 3 and the corresponding exogenous variables. There are seven exogenous variables used in forecasting with this model. Exvessel king crab price and lobster prices are published by the Alaska Department of Fish and Game and Urner Barry Publications, respectively. These are the same sources used in the original data set, so if the values are measured with error, the error should be consistent throughout the original and simulation data sets. The 1989 average exvessel price for 1989 Bristol Bay red king crab was $5.00/lb. The midrange wholesale price for 8–10 oz. Australian rock lobster tails was $17.88 in October 1989 and $19.13 in September 1990.

The five remaining exogenous variables are the beginning of month stocks for each size class, measures which had to be approximated. Values for these variables were generated by assuming that the proportion of the 1989-90 red king crab harvest sold as legs and claws in the U.S. market (12% processed weight) mirrored proportions in the previous two marketing years. This quantity was distributed among the five size classes based on the general distribution in the historical data set: 4% Red 9/12, 30% Red 12/14, 34% Red 14/16, 26% Red 16/20, and 6% Red 20/25. These total available supply estimates were assumed to be sold throughout the year at the historical rate of sales for each size class. There was very little difference in predicted prices based on the 1987–88 monthly rate of sales versus the 1988–89 monthly rate of sales. Predicted prices are based on the former rate.

Under these assumptions, predicted prices for the 1989–90 marketing year were over $1.00/lb. higher than the average monthly prices derived from published information. Urner Barry was chosen as the source for "actual" prices. During the historical period, actual prices generally were within the range of prices published in the "Seafood Price Current."

The discrepancy between actual and predicted wholesale prices in 1989–90 illustrates the effect of three problems in the estimation process: (1) the inability to incorporate information about golden king crab, (2) lack of observations on variables which affect demand, and (3) only 2 years of data. Exvessel price and the assumed values for the stock variables differed very little from 1988–89 to 1989–90. Lobster prices, on the other hand, increased $2.00/lb. above the maximum observed price in the historical data set. This suggests that the estimated substitution relationship between Australian rock lobster and king crab weakens as the lobster prices increase. Additional data with greater variability would be necessary to better capture this relation.

The absence of golden king crab may contribute to the inability of this model to accurately forecast prices. Some of the substitutional relationships that presumably occur between the smaller red and larger golden king crab sizes are not being measured by other variables in the estimation process.

The model simulates 2 years of historical data well. However, once it is applied to data beyond the estimation period, both data limitations and specification problems result in inaccurate forecasts.

DISCUSSION

A size-structured shellfish population, like Alaskan king crab, poses special challenges for fishery managers and industry, alike. One often overlooked issue centers on how the size structure of the catch translates into prices and industry revenues. This investigation provides preliminary insight into wholesale price determination for frozen king crab legs and claws, which are sold by species and size in the U.S. wholesale market.

Seafood processors representing approximately 40% of domestic king crab sales in 1988 provided information on individual sales of king crab products from May 1987 through December 1989. This data was aggregated to generate a data set containing monthly observations on quantity sold and wholesale price for five sizes of red king crab. Also, some important elements of retail and wholesale demand were not available to develop a theoretically complete model specification of wholesale price.

Results suggest that processors are pricing largely on a cost-plus basis, with exvessel price determining the general price level from year to year. Total available supply of each size of crab legs and the price of substitute seafood products, in this case lobster, are also important in explaining price levels and movements over time. Adjacent sizes of red king crab are direct substitutes to wholesale buyers. Therefore, changes in price or available quantities of one size articulate price movements in other sizes.

In general, an increase in red king crab exvessel price or the price of lobster has a positive effect on wholesale prices, and an increase in the available supply of any size red king crab legs and claws has a negative effect on all wholesale prices.

The econometric model, specifically the reduced form multiplier matrix, was used to simulate wholesale price response to reducing the size limit. Such a management action would result in king crab legs and claws that are smaller than any size currently marketed (except possibly some crab imported from the Russia). While it is impossible to evaluate the price effects of a new, smaller size category, insight into the price effects were obtained by comparing predicted prices and revenues under historical conditions to predicted prices and total revenues under three different size distribution and total harvest scenarios. The results of this analysis show that prices by size can change substantially and processor revenues can rise or fall depending upon how management policies affect the size structure of the catch. A reduced size-limit policy that maintained current quotas and redistributed catch from larger sizes to the smallest size could either increase revenues very slightly or lower revenues. Revenues would climb if total catch were to increase in order to harvest more small crab.

These conclusions need to be put in a more complete policy perspective.

(1) Any reduced size limit policy will have long-term biological consequences that will alter economic performance. A 1- or 2-year perspective is inadequate to judge the full merits or drawbacks of such a policy change.

(2) Processor revenues were used to indicate changes in general industry well-being, including the fishing sector. This broad inference is based on a proportional relationship between exvessel and average wholesale prices (see Matulich et al. 1990). That is, changes in average wholesale prices (revenues) transmit exvessel price changes, even though crab is not size-graded at the exvessel level. However, there are several reasons to believe that gross wholesale revenues probably overestimate processor or industry well-being. First,

lowering the size limit will create a new, smaller size category, which will face a lower price than 20/25s. Revenue estimates would decrease. Second, processor profitability is likely to shrink if the proportion of small crab increases. Per unit processing costs are greater for smaller crab. It follows that lower processing profitability should increase the margin between wholesale and exvessel levels. Third, a smaller category of king crab may compete with the much lower priced Tanner crab, *Chinocetes bairdi,* or even golden king crab. If Tanner crab were perceived by the market as a substitute for a "25-and-up" count crab, the 25-and-up price would soften. Larger pack count king crab prices would soften.

(3) Changes in wholesale revenues do not reflect any increase in harvest efficiency associated with higher CPUE, and a higher CPUE is likely with a lower size limit. It is conceivable, though probably unlikely, that any loss in wholesale revenue could be offset by lower per-unit fishing costs and, thus, lower exvessel prices.

A variety of caveats are appropriate with this type of analysis. Serious data limitations required model specification compromises. The most notable deficiency relates to an inability to identify buyer characteristics. For example, the data represent about 800 different customers. Yet, the top five customers reflect 30%–40% of total sales by each processor. At the very least, type and size of buyer should be incorporated into the model. This was not possible for a variety of reasons, including the inability to identify the wholesale buyers from one participating processor.

Even if model specification compromises were not required, a 2-year data series is inadequate to make reliable forecasts. Moreover, the data represent only 40% of the industry. Absence of catcher-processor data raises questions regarding the generality of implied pricing behavior. Catcher-processors are becoming relatively more important in this fishery and may exhibit different market behavior. Finally, rapid expansion of the Russian king crab fishery poses special challenges for a study of this type. Russian king crab has become a near perfect substitute for Alaska king crab. Yet, the data deficiencies encountered in this study pale in comparison to that which would be encountered if the Russian product were included in the analysis.

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Table 1. Harvests of king crab by country, 1984–88 (thousand pounds live weight).

	Weight (thousands of lbs. live weight)				
Country	1984	1985	1986	1987	1988
Japan	301	772	271	455	724
Korea	13	31	11	9	22
USSR	67,010	71,984	83,475	87,356	98,476
USA	17,169	15,332	25,854	29,005	20,929
South America	6,488	6,217	6,138	5,150	5,091

SOURCE: FAO (1990).

Table 2. King crab legs and claws product forms and variable names by species and size.

Species and Size	Price Variable	Species and Size	Price Variable
Red 9/12	PR9/12	Gold 9/12	not used
Red 12/14	PR12/14	Gold 12/14	PG12/14
Red 14/16	PR14/16	Gold 14/16	PG14/16
Red 16/20	PR16/20	Gold 16/20	PG16/20
Red 20/25	PR20/25	Gold 20/25	PG20/25
Red 20/up	not used	Gold 24/up	PG24/up

Table 3. Reduced form multipliers for red king crab wholesale prices.

Dependent Variable	Explanatory Variables						
	PEXR	PLOBA	INV9/12	INV12/14	INV14/16	INV16/20	INV20/25
PR9/12	1.6230	0.2816	-0.00840	-0.00058	-0.00016	-0.00011	-0.00016
PR12/14	1.9919	0.1512	-0.00171	-0.00134	-0.00038	-0.00026	-0.00037
PR14/16	2.0117	0.1128	-0.00087	-0.00069	-0.00104	-0.00072	-0.00100
PR16/20	1.7636	0.1444	-0.00033	-0.00026	-0.00040	-0.00195	-0.00272
PR20/25	1.5346	0.1761	-0.00011	-0.00008	-0.00013	-0.00063	-0.02165

Variable Definitions:

PR - Domestic wholesale price of size-graded 20-pound box, red king crab legs and claws.

PEXR - Seasonal average exvessel price for red king crab.

PLOBA - Price of 8-10 oz. frozen Australian lobster tails, mid-Atlantic coast.

INV - Remaining annual inventory of size-graded product, seasonal year, measured in thousand pounds.

Table 4. Goodness-of-fit statistics for ex-post simulation of historical baseline data for red king crab.

Endogenous Variable	Lower Range Absolute % Error	Mean Absolute % Error	Upper Range Absolute % Error
PR9/12	0.0003	0.0184	0.0641
PR12/14	0.0014	0.0124	0.0449
PR14/16	0.0011	0.0170	0.0431
PR16/20	0.0004	0.0135	0.0362
PR20/25	0.0004	0.0211	0.0892

Table 5. Theil's statistics for ex-post simulation of historical baseline data for red king crab.

Endogenous Varible	(U) Inequality Coefficient	(U^M) Bias Proportion	(U^R) Regression Proportion	(U^D) Disturbance Proportion
PR9/12	0.0122	0.000	0.034	0.966
PR12/14	0.0085	0.008	0.068	0.924
PR14/16	0.0107	0.001	0.01	0.985
PR16/20	0.0093	0.000	0.025	0.975
PRRR20/25	0.0135	0.001	0.008	0.991

Table 6. Total pounds of red king crab sold and distribution by size under historical conditions and three alternative policy scenarios, 1987–88 and 1988–89.

			Policy Scenario		
Year	Product	Historical	1	2	3
1987–88					
	9/12	46,480	44,539	35,895	46,480
		4.44%	4.25%	3.43%	4.27%
	12/14	306,380	293,870	295,804	306,380
		29.23%	28.04%	28.23%	28.13%
	14/16	357,080	342,165	347,157	357,080
		34.07%	32.65%	33.13%	32.79%
	16/20	274,390	262,929	264,363	274,390
		26.18%	25.09%	25.22%	25.19%
	20/25	63,690	104,802	104,802	104,802
		6.08%	10.00%	10.00%	9.62%
Total Sales		1,048,020	1,048,020	1,048,020	1,089,132
		100.00%	100.00%	100.00%	100.00%
1988–89					
	9/12	22,580	21,549	14,376	22,580
		3.23%	3.08%	2.06%	3.09%
	12/14	201,460	192,259	193,936	201,460
		28.80%	27.49%	27.72%	27.61%
	14/16	224,520	214,266	217,020	224,520
		32.10%	30.63%	31.03%	30.77%
	16/20	211,120	201,478	203,729	211,120
		30.18%	28.80%	29.12%	28.94%
	20/25	39,820	69,950	69,950	69,950
		5.69%	10.00%	10.00%	9.59%
Total Sales		699,500	699,500	699,500	729,630
		100.00%	100.00%	100.00%	100.00%

Table 7. Weighted average annual wholesale prices by size (in dollars/lb.) of red king crab legs and claws: historical and alternative policy scenarios.

			Policy Scenario		
Year	Product	Historical	1	2	3
1987–88					
	9/12	$10.25	$10.27	$10.31	$10.25
	12/14	9.91	9.91	9.92	9.90
	14/16	9.30	9.29	9.29	9.27
	16/20	8.75	8.69	8.69	8.67
	20/25	7.89	7.38	7.38	7.38
1988–89					
	9/12	12.09	12.10	12.13	12.09
	12/14	12.19	12.20	12.20	12.19
	14/16	11.64	11.64	11.64	11.63
	16/20	10.79	10.77	10.77	10.76
	20/25	9.78	9.41	9.41	9.41

Table 8. Total revenue from red king crab sales under historical baseline conditions and three scenarios of sales and product distribution (value as of October 1, 1989).

		Policy Scenario		
Product	Historical	1	2	3
9/12	$ 781,401	$ 755,948	$ 575,070	$ 781,172
12/14	5,726,174	5,530,418	5,525,044	5,721,994
14/16	6,062,893	5,976,899	5,877,960	6,049,278
16/20	4,803,874	4,688,176	4,609,274	4,552,131
20/25	937,131	1,504,613	1,502,655	1,501,883
Total	$18,311,473	$18,456,054	$18,090,003	$18,606,458

APPENDIX

Appendix A. Definitions, units of measure, and data sources for all model variables.

Variable Name	Variable Definition
PR9/12	Weighted average price per pound by month for 9/12 count frozen Red king crab legs and claws packed in 20-pound boxes. Units: Dollars Source: Industry survey Table: B.1
PR12/14	Weighted average price per pound by month for 12/14 count frozen Red king crab legs and claws packed in 20-pound boxes. Units: Dollars Source: Industry survey Table: B.1
PR14/16	Weighted average price per pound by month for 14/16 count frozen Red king crab legs and claws packed in 20-pound boxes. Units: Dollars Source: Industry survey Table: B.1
PR16/20	Weighted average price per pound by month for 16/20 count frozen Red king crab legs and claws packed in 20-pound boxes. Units: Dollars Source: Industry survey Table: B.1
PR20/25	Weighted average price per pound by month for 20/25 count frozen Red king crab legs and claws packed in 20-pound boxes. Units: Dollars Source: Industry survey Table: B.1
QS9/12	Total number of pounds of 9/12 count frozen Red king crab legs and claws sold each month by firms cooperating with industry survey. Units: Pounds Source: Industry survey Table: B.2
QS12/14	Total number of pounds of 12/14 count frozen Red king crab legs and claws sold each month by firms cooperating with industry survey. Units: Pounds Source: Industry survey Table: B.2

Variable Name	Variable Definition
QS14/16	Total number of pounds of 14/16 count frozen Red king crab legs and claws sold each month by firms cooperating with industry survey. Units: Pounds Source: Industry survey Table: B.2
QS16/20	Total number of pounds of 16/20 count frozen Red king crab legs and claws sold each month by firms cooperating with industry survey. Units: Pounds Source: Industry survey Table: B.2
QS20/25	Total number of pounds of 20/25 count frozen Red king crab legs and claws sold each month by firms cooperating with industry survey. Units: Pounds Source: Industry survey Table: B.2
INV9/12	Inventory drawdown variable. Sales of 9/12 count Red king crab legs and claws were summed from October through September of each year. Each month, sales of the product were subtracted from the annual total to determine the amount of product remaining for sale during the year. Units: Pounds Source: Industry survey Table: B.2
INV12/14	Inventory drawdown variable. Sales of 12/14 count Red king crab legs and claws were summed from October through September of each year. Each month, sales of the product were subtracted from the annual total to determine the amount of product remaining for sale during the year. Units: Pounds Source: Industry survey Table: B.2
INV14/16	Inventory drawdown variable. Sales of 14/16 count Red king crab legs and claws were summed from October through September of each year. Each month, sales of the product were subtracted from the annual total to determine the amount of product remaining for sale during the year. Units: Pounds Source: Industry survey Table: B.2
INV16/20	Inventory drawdown variable. Sales of 16/20 count Red king crab legs and claws were summed from October through September of each year. Each month, sales of the product were subtracted from the annual total to determine the amount of product remaining for sale during the year.

Variable Name	Variable Definition
	Units: Pounds Source: Industry survey Table: B.2
INV20/25	Inventory drawdown variable. Sales of 20/25 count Red king crab legs and claws were summed from October through September of each year. Each month, sales of the product were subtracted from the annual total to determine the amount of product remaining for sale during the year. Units: Pounds Source: Industry survey Table: B.2
PEXR	Average seasonal exvessel price paid in Alaska for red king crab. There are two values for this variable: \$4.00 for the 1987–88 season, and \$5.08 for the 1988–89 season. Source: Alaska Department of Fish and Game, Reports to the Board of Fisheries. Units: Dollars
PLOBA	Average F.O.B. warehouse (first receiver) price per pound of frozen, 8–10 oz. Australian lobster tails on the Mid-Atlantic coast. Reported bi-weekly prices were averaged to a monthly price by multiplying each price by the number of days this price occurred, summing over the month, and dividing the sum by the total number of days in the month. Units: Dollars Source: Urner Barry Seafood Price Current Table: B.3
RESTUNADJ	Monthly expenditures in restaurants, cafeterias, and lunchrooms, excluding purchases of alcohol. Figures are unadjusted for seasonal variation. Units: Million dollars Source: U.S. Department of Commerce
POP	Estimated monthly population in the U.S. Units: Persons Source: Statistical Abstract of the U.S.
PCREST	RESTUNADJ/POP Per capita monthly expenditures in restaurants, cafeterias, and lunchrooms, excluding purchases of alcohol. Units: Dollars Source: Calculated Table: B.3

Appendix Table B. Weighted average monthly wholesale price for size-graded red king crab legs and claws sold in the U.S. by participating processors, 1987–89.

Year	Month	PR9/12	PR12/14	PR14/16	PR16/20	PR20/25
1987	Oct	$ 0.00	$ 9.56	$ 8.72	$ 8.39	$ 7.45
	Nov	10.90	9.99	9.22	8.70	8.01
	Dec	10.38	9.86	9.26	8.78	8.13
1988	Jan		9.84	9.23	8.67	7.55
	Feb	10.45	9.80	9.27	8.61	7.19
	Mar	10.35	9.83	9.22	8.70	7.65
	Apr	10.32	9.86	9.25	8.71	7.27
	May	10.35	10.04	9.38	8.98	7.74
	Jun	10.35	9.91	9.32	9.06	8.14
	Jul	10.35	9.81	9.54	8.91	8.15
	Aug	10.33	9.77	9.60	9.10	7.98
	Sep	10.39	9.74	9.87	9.05	8.18
	Oct	10.82	11.11	10.82	10.12	8.89
	Nov	11.59	12.20	10.65	10.67	9.72
	Dec	12.54	12.16	11.70	10.65	9.74
1989	Jan	12.56	12.06	11.77	10.66	9.68
	Feb	12.35	11.74	11.07	10.62	9.72
	Mar	12.33	12.29	11.65	10.59	9.63
	Apr	12.31	12.12	11.44	10.57	9.94
	May	12.47	12.22	11.42	10.68	10.46
	Jun	12.55	12.52	11.81	10.76	10.48
	Jul	12.65	12.48	11.75	10.90	10.46
	Aug	12.60	12.69	11.90	11.72	10.75
	Sep	12.79	11.46	11.41	10.81	9.28

Appendix Table C. Monthly sales and stocks remaining (lbs) in inventory of red king crab legs and claws sold in the U.S. by four processors, 1987–89.

		---- Red 9/12 ----		---- Red 12/14 ----		---- Red 14/16 ----		---- Red 16/20 ----		---- Red 20/25 ----	
Year	Month	Sales QS9/12	Inventory INV9/12	Sales QS12/14	Inventory INV12/14	Sales QS14/16	Inventory INV14/16	Sales QS16/20	Inventory INV16/20	Sales QS20/25	Inventory INV20/25
1987	Oct	0	46,480	12,080	306,680	20,060	357,080	15,740	274,390	1,700	63,690
	Nov	440	46,480	7,520	294,600	23,880	337,020	25,480	258,650	4,890	61,990
	Dec	3,280	46,040	73,120	287,080	12,360	313,140	17,180	233,170	1,940	57,100
1988	Jan	0	42,760	11,820	213,960	41,280	300,780	19,310	215,990	7,780	55,160
	Feb	4,000	42,760	6,340	202,140	31,300	259,500	49,620	196,680	500	47,380
	Mar	220	38,760	10,000	195,800	35,620	228,200	37,620	147,060	10,000	46,880
	Apr	4,420	38,540	38,800	185,800	58,220	192,580	35,080	109,440	440	36,880
	May	240	34,120	11,380	147,000	54,660	134,360	22,060	74,360	720	36,440
	Jun	1,240	33,880	47,080	135,620	47,020	79,700	22,080	52,300	4,440	35,720
	Jul	780	32,640	31,780	88,540	16,540	32,680	10,540	30,220	5,220	31,280
	Aug	26,680	31,860	42,500	56,760	14,980	16,140	15,680	19,680	9,580	26,060
	Sep	5,180	5,180	14,260	14,260	1,160	1,160	4,000	4,000	16,480	16,480
	Oct	740	22,580	9,260	201,460	5,760	224,520	14,320	211,120	2,880	39,820
	Nov	5,080	21,840	13,520	192,200	17,760	218,760	19,860	196,800	9,660	36,940
	Dec	6,400	16,760	15,860	178,680	25,580	201,000	11,140	176,940	4,100	27,280
1989	Jan	2,400	10,360	9,160	162,820	12,340	175,420	11,980	165,800	1,320	23,180
	Feb	2,400	7,960	28,520	153,660	19,900	163,080	8,340	153,820	940	21,860
	Mar	720	5,560	13,840	125,140	16,540	143,180	28,300	145,480	7,900	20,920
	Apr	2,920	4,840	19,560	111,300	18,180	126,640	27,860	117,180	4,500	13,020
	May	260	1,920	21,680	91,740	42,540	108,460	32,100	89,320	1,320	8,520
	Jun	240	1,660	17,680	70,060	15,420	65,920	25,260	57,220	3,460	7,200
	Jul	240	1,420	18,020	52,380	20,980	50,500	14,920	31,960	920	3,740
	Aug	580	1,180	30,280	34,360	14,060	29,520	6,520	17,040	2,720	2,820
	Sep	600	600	4,080	4,080	15,460	15,460	10,520	10,520	100	100

Appendix Table D. Exvessel price for red king crab, wholesale price for Australian rock lobster, and per capita expenditures at eating places, 1987–89.

Year	Month	Exvessel Price (PEXR)	Lobster Price (PLOBA)	Per Capita Expenditures (PCREST)
1987	Oct	$4.00	$17.17	$27.77
	Nov	$4.00	$17.66	$26.28
	Dec	$4.00	$17.08	$27.36
1988	Jan	$4.00	$16.18	$25.36
	Feb	$4.00	$15.42	$25.21
	Mar	$4.00	$15.29	$27.24
	Apr	$4.00	$15.30	$28.14
	May	$4.00	$15.30	$29.02
	Jun	$4.00	$15.06	$29.53
	Jul	$4.00	$14.43	$30.84
	Aug	$4.00	$14.21	$31.59
	Sep	$4.00	$13.39	$29.57
	Oct	$5.08	$12.92	$30.40
	Nov	$5.08	$14.25	$28.42
	Dec	$5.08	$14.38	$29.94
1989	Jan	$5.08	$14.38	$27.47
	Feb	$5.08	$14.40	$26.26
	Mar	$5.08	$14.61	$29.18
	Apr	$5.08	$14.63	$29.50
	May	$5.08	$15.76	$30.43
	Jun	$5.08	$16.38	$30.50
	Jul	$5.08	$16.47	$30.94
	Aug	$5.08	$16.88	$31.45
	Sep	$5.08	$17.29	$29.20

Appendix Table E. Simulated wholesale prices (dollars/lb) red king crab legs and claws under historical conditions and three reduced size-limit scenarios.

		Red 9/12				Red 12/14				Red 14/16			
			Scenario				Scenario				Scenario		
Year	Month	Hist	1	2	3	Hist	1	2	3	Hist	1	2	3
1987	Oct	$10.66	$10.68	$10.75	$10.65	$ 9.84	$ 9.86	$ 9.87	$ 9.83	$ 9.10	$ 9.09	$ 9.09	$ 9.06
	Nov	10.81	10.83	10.90	10.81	9.95	9.96	9.97	9.93	9.20	9.19	9.19	9.16
	Dec	10.66	10.68	10.75	10.66	9.89	9.90	9.91	9.87	9.18	9.18	9.18	9.15
1988	Jan	10.48	10.50	10.57	10.48	9.86	9.87	9.88	9.85	9.16	9.16	9.16	9.13
	Feb	10.29	10.30	10.37	10.28	9.79	9.80	9.81	9.78	9.15	9.14	9.15	9.12
	Mar	10.30	10.31	10.37	10.29	9.81	9.82	9.83	9.80	9.21	9.20	9.21	9.18
	Apr	10.32	10.34	10.40	10.32	9.85	9.86	9.87	9.84	9.29	9.29	9.29	9.27
	May	10.39	10.41	10.46	10.39	9.94	9.95	9.96	9.93	9.41	9.40	9.40	9.39
	Jun	10.35	10.36	10.41	10.34	9.95	9.95	9.96	9.94	9.47	9.45	9.46	9.44
	Jul	10.22	10.23	10.28	10.21	9.94	9.94	9.95	9.94	9.50	9.48	9.49	9.48
	Aug	10.18	10.19	10.24	10.18	9.96	9.96	9.97	9.96	9.53	9.51	9.52	9.51
	Sep	10.21	10.21	10.22	10.21	9.96	9.95	9.96	9.95	9.52	9.51	9.51	9.51
	Oct	11.51	11.52	11.58	11.51	11.61	11.62	11.63	11.60	11.09	11.09	11.09	11.06
	Nov	11.90	11.91	11.96	11.90	11.83	11.84	11.85	11.82	11.27	11.26	11.27	11.24
	Dec	11.99	12.00	12.04	11.99	11.89	11.90	11.91	11.88	11.34	11.34	11.34	11.32
1989	Jan	12.06	12.07	12.09	12.06	11.94	11.95	11.95	11.93	11.40	11.40	11.40	11.38
	Feb	12.10	12.10	12.12	12.09	11.97	11.98	11.98	11.96	11.43	11.43	11.43	11.41
	Mar	12.20	12.20	12.21	12.09	12.05	12.06	12.06	12.04	11.50	11.50	11.50	11.49
	Apr	12.22	12.23	12.24	12.22	12.09	12.10	12.10	12.09	11.56	11.56	11.56	11.55
	May	12.58	12.59	12.59	12.58	12.31	12.31	12.31	12.31	11.75	11.75	11.75	11.74
	Jun	12.78	12.79	12.79	12.78	12.46	12.46	12.46	12.45	11.90	11.90	11.90	11.89
	Jul	12.83	12.83	12.83	12.83	12.51	12.51	12.51	12.51	11.96	11.96	11.96	11.96
	Aug	12.96	12.96	12.97	12.96	12.61	12.61	12.61	12.61	12.05	12.05	12.05	12.05
	Sep	13.10	13.10	13.10	13.10	12.72	12.72	12.72	12.72	12.14	12.14	12.14	12.14

Appendix Table E. (Continued)

Year	Month	Red 16/20				Red 20/25			
		Hist	Scenario			Hist	Scenario		
			1	2	3		1	2	3
1987	Oct	$ 8.59	$ 8.51	$ 8.51	$ 8.48	$ 7.53	$ 6.65	$ 6.65	$ 6.64
	Nov	8.70	8.63	8.62	8.60	7.67	6.81	6.81	6.80
	Dec	8.70	8.62	8.62	8.60	7.69	6.91	6.90	6.90
1988	Jan	8.63	8.56	8.56	8.53	7.60	6.83	6.83	6.83
	Feb	8.60	8.54	8.54	8.51	7.65	6.99	6.99	6.99
	Mar	8.69	8.63	8.63	8.61	7.67	7.02	7.02	7.02
	Apr	8.81	8.76	8.76	8.75	7.92	7.41	7.41	7.41
	May	8.92	8.86	8.86	8.85	7.96	7.46	7.46	7.45
	Jun	8.95	8.90	8.90	8.89	7.96	7.46	7.46	7.46
	Jul	8.95	8.90	8.90	8.89	7.97	7.53	7.53	7.53
	Aug	8.97	8.92	8.92	8.92	8.05	7.69	7.69	7.69
	Sep	8.93	8.90	8.90	8.90	8.14	7.91	7.91	7.90
	Oct	10.16	10.10	10.10	10.07	9.03	8.38	8.38	8.38
	Nov	10.39	10.34	10.33	10.31	9.34	8.74	8.74	8.73
	Dec	10.48	10.45	10.45	10.43	9.58	9.14	9.14	9.14
1989	Jan	10.53	10.51	10.50	10.49	9.68	9.31	9.31	9.31
	Feb	10.57	10.54	10.54	10.53	9.73	9.37	9.37	9.37
	Mar	10.64	10.61	10.61	10.59	9.79	9.46	9.46	9.45
	Apr	10.73	10.71	10.71	10.70	9.99	9.78	9.78	9.78
	May	10.97	10.96	10.96	10.95	10.31	10.17	10.17	10.17
	Jun	11.15	11.14	11.14	11.13	10.47	10.36	10.36	10.36
	Jul	11.23	11.23	11.23	11.22	10.58	10.52	10.52	10.52
	Aug	11.33	11.33	11.33	11.33	10.69	10.64	10.64	10.64
	Sep	11.43	11.43	11.43	11.43	10.83	10.83	10.83	10.83