AN ECONOMIC OVERVIEW OF DUNGENESS CRAB (*CANCER MAGISTER*) PROCESSING IN CALIFORNIA

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ABSTRACT

Dungeness crab (*Cancer magister*) was among the three most valuable commercial fisheries in California in seven of the last ten years. The "sex-size-season" regulatory system in California induces an annual derby fishery that results in a temporally compressed pulse of landings. The fishery relies on a few large receiver/processors capable of freezing and storing large quantities of crab. Research on former derby fisheries indicates that improved economic conditions (more valuable fresh product forms and more competitive processing) can be obtained if landings are temporally distributed. Consequently, questions have been raised about the current status of the Dungeness crab processing industry and whether economic conditions could be improved by eliminating the derby fishery. This article addresses part of the question by providing baseline economic information for this industry, including the mix of product forms and prices, value added, capital stock, and employment.

INTRODUCTION

Dungeness crab (*Cancer magister*), traditionally an important fishery in central and northern California, was among the three most valuable fisheries in California in seven of the last ten years. Since the mid-1970s the California/Oregon/Washington Dungeness crab fishery has experienced a sharp increase in number of traps fished. According to Didier (2002), there were an estimated 130,130 traps fished in the California/Oregon/Washington fishery in the 1975–76 season. In the 2000–2001 season Oregon and Washington combined had over 200,000 traps being fished (Didier 2002). From a recently completed survey of California Dungeness crab permit holders, we estimate that at least 172,000 traps were being fished in California in the 2001–2002 season.[1] In contrast, an economic analysis of the Dungeness crab fishery in the 1970s concluded that net economic benefits from the California/Oregon/Washington fishery would be maximized with a combined average effort level of around 60,000 traps across all three states (Pacific Marine Fisheries Commission 1978). Therefore, it is possible that combined current trap levels (about 375,000 traps) are more than six times the optimal number of traps.

This increase in effort combined with the "sex-size-season" regulatory system in California, Oregon, and Washington induces an annual "race for crab" or derby fishery that results in a temporally compressed pulse of landings. The commercial fishing season in California for Dungeness crab starts on 15 November (central coast) or 1 December (north coast), subject to meat yield testing and price negotiations between fishers and receiver/processors, and lasts until 30 June (central coast) or 15 July (north coast). (The season is of similar duration in Oregon and Washington.) Despite this long season, in recent years more than 70% of annual landings have occurred from 15 November to 31 December.[2] Due to this pulse of landings, the fishery relies on a few large receiver/processors capable of freezing and storing large quantities of crab. Research on former derby fisheries indicates that improved economic conditions (more valuable fresh product forms and more competitive processing) can be obtained if landings are temporally distributed. Consequently, questions have been raised about the current status of the Dungeness crab processing industry and whether eliminating derby conditions would improve economic conditions in the fishery. We address part of the question by providing baseline economic information for this industry, including the mix of product forms and prices, value added, capital investment, and employment.[3]

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[1]For a copy of the survey questionnaire, contact the authors.

[2]This pattern of temporal compression of Dungeness crab landings in California can be observed as far back as the early 1980s and also occurs in Oregon (Kaiser et al. 2001) and to some extent in Washington (PSMFC 1993). In contrast, between the 1950s and the mid-1970s only 30% to 40% of statewide landings occurred between 15 November and 31 December, and approximately 10% of annual landings were made in each of the months of February, March, and April.

[3]To more fully answer this question one would need to engage in market research to analyze the potential and the profitability associated with increasing the demand for live and fresh Dungeness crab outside of the traditional holiday season.

BACKGROUND

Fisheries management affects the structure of the fish-processing industry, the types of fish products sold by processors, and the marketing channels through which these fish products flow. Derby fisheries tend to promote overcapitalization by fishers, hazardous fishing conditions, and larger, more capital-intensive processors with freezing capacity adapted to the large pulse of landings. Prominent among the various proposed remedies for derby fisheries are individual quotas (IQs).[4] There is some evidence, summarized below, that IQs have resulted in higher ex-vessel prices, an increase in the processing of more valuable fresh product forms relative to frozen product forms, and structural changes in the fish-processing sector.

The potentially beneficial impacts of an IQ system on product forms, prices, and the structure of the fish-processing industry are illustrated by the British Columbian Pacific halibut (*Hippoglossus stenolepis*) fishery. As Casey et al. (1995) observe, attempts at managing this fishery by way of limited season openings resulted in overcapitalization, which in turn necessitated progressively abbreviated openings. By 1990 the annual fishing season had been compressed to a few days, and the resulting pulse of landings was largely processed into frozen product forms. In 1993, two years after an individual vessel quota (IVQ) system was implemented, landings were spread over eight months. This extended season led to an increase in fresh product forms and ex-vessel prices. While in 1989 the share of British Columbian halibut sold as a fresh product form was 42%, by 1993 this figure had increased to 94%. Moreover, the IVQ system encouraged the proliferation of smaller processors exploiting new niche markets for fresh fish.[5] More processors competing for fish bid up ex-vessel prices, creating financial benefits for fishers. Herrmann (1996) estimates that the IVQ system generated $23.22 million in additional revenue to fishers over the first four years of the program due to improved ex-vessel price. An IQ system for Alaskan halibut and sablefish was implemented in 1995.[6]

In 1986 New Zealand implemented an individual transferable quota (ITQ) system on some select fisheries in an attempt to conserve fish stocks. A 1987 survey by Dewees (1989) found that 77% of the fishers and processors had already significantly changed their operations, and notable among these was that fishers had placed more emphasis on new handling techniques to add value to their catch.[7] Export of live rock lobster (*Jasus edwardsii*) increased from 1,947 metric tons in 1990 to 2,722 metric tons in 1993. Australia and Tasmania have since also implemented ITQs. The South Australian rock lobster fishery has shown a 67% increase in real ex-vessel revenue between 1991 and 1998 in the northern zone, due to a 7% increase in landings and a 77% increase in nominal price (Donohue and Barker 2000). The southern zone showed a 33% increase in real ex-vessel value over the same period.

While trap limits (or trap certificates) have been a popular management tool for controlling effort in crustacean fisheries, there is little evidence to date indicating that they have had a significant impact in either reducing effort or increasing the proportion of more valuable product forms. For example, participants in the Maine lobster (*Homarus americanus*) fishery agreed to a trap quota system to address concerns over escalating trap numbers (Acheson 2001, 1998). The Maine trap-reduction program was widely seen as a failure in spite of initial participant support.[8] Between 1995 and 1998, 25% of the Maine lobster fleet increased their trap counts by over 200 traps, while only 17% of the fleet experienced any level of reduction in traps fished. Florida's spiny lobster (*Panulirus argus*) fishery faced similar overcapitalization problems and implemented a tradable trap certificate program in 1992. Although this program has reduced the total number of traps fished, Milon and Larkin (2000) estimate that the current number of traps is still roughly twice the optimal level, and they are skeptical that this program will achieve the optimal level of effort.[9]

METHODS

We focus our analysis on the firms that receive and process Dungeness crab landed in California and on the

[4]IQs assign a share of a total allowable catch (TAC) to individual fishers (IFQs), vessels (IVQs), or communities (CFQs), and may be transferable (ITQs). Fishers can fill their quota at any time during the open season, thereby eliminating derby effects in a fishery.

[5]Note, however, that the transition likely imposed costs on the large capital-intensive processors with freezer capacity adapted to the former pulse of landings.

[6]The National Research Council (1999) cites anecdotal evidence that increasing numbers of Alaskan halibut fishers are bypassing traditional processing market channels and marketing directly to wholesalers and retailers. The same report cited testimony from processors indicating that the shift from large pulses of landings to a more even flow of landings had disadvantaged some of their operations, noting that "it is reasonable to assume that processing operations that had relied on large pulses of product for processing for the frozen market and had failed to modify their operations to accommodate the longer IFQ season would be less profitable as season lengthened" (p. 390).

[7]Similarly, following a change to an IQ system, the processing sector in Iceland has experienced a reduction in freezing capacity and in the number of large onshore processors, due in part to an increase in higher valued fresh product forms and at-sea processing.

[8]Equal trap limits set on all vessels allowed smaller vessels to increase the number of traps fished over the term of the program (Acheson 2001).

[9]Trap limits are finding their way into West Coast Dungeness crab fisheries. Washington's Fish and Wildlife Commission recently adopted a three-tiered Dungeness crab trap-limit system that has resulted in a 6.6% reduction in the total number of traps in the fishery. Moreover, a 2001 survey indicated that 86.5% of Oregon's Dungeness crab fishers favored trap limits (Kaiser et al. 2001). Fisher groups have discussed trap limits in California, but to date they have been unable to agree on any management measures to address economic conditions in the fishery.

product forms they sell. Our interviews included six processing firms in California and southern Oregon that purchased 60% of the crab landed in California in 2000. While economic conditions in the fishery and the processing industry are similar in Oregon and Washington, analysis of the combined California/Oregon/Washington Dungeness crab fishery is beyond the scope of the present analysis.

Value Added

At any given market-mediated stage of production, value added is measured as total revenue generated from sales of the product at that stage of production minus the value added at the previous stages of production (if any). Thus value added at the harvesting stage of production in a capture fishery is simply total revenue to the fishers. In contrast, value added at the receiving/processing stage of production (including any integrated wholesale distribution functions) is total revenue from sales of processed fish products minus the value of the fish received from the fishers. Value added represents income that flows to those who supply the capital, labor, entrepreneurship, and intermediate good and service inputs that are assembled together in production. Value added also includes tax income provided to federal, state, and local government (Hackett 2002).[10]

The term *percent value added* will be used here to describe processor value added as a percentage of the cost of purchased crab. Processor product mix ratios will also be crucial for the analysis. These ratios will aid in understanding the current flow of crab products through markets. The product mix will be important in analyzing the current production status as well as potential changes due to temporal distribution of product flow.

Data

The data used in this report come from both primary and secondary sources. In all cases these data are confidential and/or proprietary in nature. Data on vessel landings are derived from existing fish ticket data gathered by the California Department of Fish and Game (CDFG) and archived by the Pacific States Marine Fisheries Commission (PSMFC) in their PacFIN database. Each ticket contains information on quantity and revenue of crab landed and sold. Fish tickets also identify the receiver/processors who buy the crab, which is essential to the estimation of processor value added employed here. Product form, price, and product mix information were collected from the processors through on-site interviews and completion of a questionnaire.[11] The survey instrument also gathered information on capital investment and employment. Price per pound for various product forms can vary substantially over a given season, and so we asked processors to report average or typical price per pound for various product forms. The mix of various crab products made by processors was generally reported in two forms, either total pounds of each product form produced, or the percentage of purchased crab going into each product form.

In order to determine value added by processors we acquired authorization to access confidential data on purchases of crab by various processors in 2000 from fish ticket data archived by the PSMFC in the PacFIN database. The data covered purchases of crab landed at the four north coast ports in California (Fort Bragg, Eureka, Trinidad, and Crescent City). The original scope of this study was focused on the north coast ports of California, but later the scope was expanded to include the central coast Dungeness crab fishery. Unfortunately a subsequent supplemental request for 2001 central coast data, and for season rather than annual year data, was rejected by CDFG due to a dramatic change in data access policy that currently eliminates all independent researcher access to any confidential fish ticket data.

Due to the incomplete data set from CDFG a number of adjustments and estimates had to be made in our analysis. While the data we initially received from PacFIN was annual year data, we later learned that processors generally track their data based on fishing seasons (November/December through July). Because we could not go back and get processor purchase data from PacFIN based on fishing season, we were forced to assume that a processor's purchase share of statewide landings based on annual year data is equivalent to what it would be based on fishing season data. Consequently, the estimates reported as "2000" in this article refer to the 1999–2000 fishing season, while estimates reported as "2001" refer to the 2000–2001 season.

Moreover, since the PacFIN dataset provided to us only included purchases of crab landed at the four north coast ports, we had to estimate processor purchases of crab statewide based on the known proportion of north coast landings purchased by each processor. Specifically, we first computed the share of north coast landings purchased by each processor and then assumed that the same proportion applied to their statewide landings. Thus, if a processor received 20% of all north coast landings, we assumed that the processor had likewise received 20% of statewide landings. Since the four north coast ports generally include most of the state's overall landings (between approximately 70% and 90% of statewide landings

[10]Note that value added does not necessarily include all of the possible positive and negative economic impacts of commercial fishing; for example, the income to employees of a processing facility is included in value added, but the additional community income generated by workers spending their paychecks at local grocery stores is not.

[11]For interview questions and methods, contact the authors.

over the last ten years), our projection of central coast purchases covers less than 30% of statewide landings.

Due to the natural fluctuation in Dungeness crab landings it is desirable to generate analysis for more than one year, and consequently we sought out data for 2000 and 2001. Unfortunately, the change in data-management policy at CDFG prevented us from acquiring 2001 fish ticket data indicating the quantity and price of crab received by individual processors, a situation that resulted in our having to estimate those purchases.[12] We used the statewide weighted average ex-vessel price per pound for 2001 to reflect the cost per pound of purchased crab for each processor. We developed two scenarios for estimating 2001 processor purchases to indicate the sensitivity of our results to different estimation approaches. Scenarios with the suffix "00" in Table 1 involved estimating 2001 processor purchases by assuming that a processor's share of total statewide landings in 2001 was the same as its known share of total statewide purchases in 2000. Since year-to-year landings and processor volumes fluctuate, a second scenario was developed (designated by the suffix "9800" in Table 1) by assuming that a processor's known share of total statewide landings in 2001 is equal to the average share of its known total statewide landings purchased over 1998–2000.

A final data issue concerns the extent to which the sample of processors interviewed for this study is representative of all processors that purchase Dungeness crab landed in California. We succeeded in surveying six processors in California and southern Oregon that together purchased 60% of all crab landed in California in 2000. We use these data to develop estimates for all processors that purchased Dungeness crab landed in California. The processors we surveyed tended (with one exception) to be the larger operators; this resulted in a sample bias in our processor data. The bias exists because small processors frequently lack fixed facilities and may only operate for a number of weeks each year, making them difficult to locate and interview. For example, some small processors purchase crab at the dock and drive the live crab to urban seafood markets. Small processors tend to specialize in live and fresh crab and lack the facilities to process frozen product forms (some of which later undergoes secondary processing into a picked meat product). Thus the "in-sample" data are biased toward frozen product forms.

Consequently, we created two additional scenarios based on different methods for extrapolating industry-wide product forms, prices, and value added from our survey data. One of these, designated with the letters "EX" in Table 1, is based on a simple extrapolation of the data from our overall survey data to processors outside of our sample. The other, designated with the letters "SM" in Table 1, is based on an extrapolation of the data from the small processor in our sample to processors outside of our sample.[13]

TABLE 1
Estimate Scenarios

Scenario	Description
2000EX	2000 processor estimates, extrapolating in-sample processor data to out-of-sample processors
2000SM	2000 processor estimates, extrapolating small-processor in-sample data to out-of-sample processors
2001EX00	2001 processor estimates, extrapolating in-sample processor data to out-of-sample processors, based on processor purchases in 2000
2001SM00	2001 processor estimates, extrapolating small-processor in-sample data to out-of-sample processors, based on processor purchases in 2000
2001EX9800	2001 processor estimates, extrapolating in-sample processor data to out-of-sample processors, based on average processor purchases in 1998–2000
2001SM9800	2001 processor estimates, extrapolating small-processor in-sample data to out-of-sample processors, based on average processor purchases in 1998–2000

Thus, we have four scenarios for estimating product mix, product form prices, and value added for processors purchasing all California Dungeness crab landings in 2001 and two scenarios for estimating landings for 2000, as shown in Table 1.

ANALYSIS AND RESULTS

Analytical Approaches

In order to perform value added analysis we had to yield-adjust product form quantities and prices to place them on a common basis with the original whole purchased crab ("round").[14] Yield adjustment is used to determine the percentage of the original whole crab by weight that remains in the product form after processing. For example, from Table 2 we can see that the "whole cooked" product form represents 87.5% of a whole crab by weight (due to loss of fluids), whereas the "picked meat" product form represents 25% of a whole crab by weight (due to fluids, viscera, and shell). Yield-adjusted price per pound for each product form was similarly calculated by multiplying the product form price per pound by the yield figures in Table 2. We then calculated the percentage of total yield-adjusted production going to each product form for each processor in our survey.

[12]The CDFG policy change occurred in November 2001, before 2001 fish ticket data were fully tabulated and archived in the PacFIN database.

[13]The small processor scenarios rely on data from one small processor, which lends a degree of uncertainty to the conclusions that follow.

[14]We also had to convert any specific product form quantities reported by processors into percentages of total purchases allocated to each product form.

TABLE 2
Dungeness Crab Product Forms and Yield

Product form	Yield	Description
Whole cooked	87.5%	Frozen or fresh, cooked in brine; frozen product glazed to prevent freezer burn
Clean and cracked	87.5%	Same as whole cooked product, except legs are scored, often with band saw, for easier access to meat
Frozen section	~58%	Crab split into legs and sections, glazed
Live	~100%	
Picked meat	25%	Whole crab is blanched, hand picked with the picked meat sold fresh, frozen, or canned

Source: Processor interviews.

TABLE 3
California Dungeness Crab Landings, Value Added, and Price

Season	Quantity landed, in lb (kg)	Ex-vessel value added	Price per lb (kg)
1999-2000	8,769,512 (3,977,013)	$17,799,767	$2.03 ($4.48)
2000-2001	5,646,772 (2,560,894)	$12,616,251	$2.23 ($4.92)

Source: Processor interviews and PacFIN database.

TABLE 4
Industry-wide Estimates for Weighted Average Price (WAP), Value Added, and Percent Value Added for California Dungeness Crab

Scenario	WAP per lb (kg)	Value added	Percent value added
2000EX	$3.04 ($6.70)	$8,831,287	49.6
2000SM	$2.99 ($6.59)	$8,448,237	47.5
2001EX00	$2.89 ($6.37)	$3,676,024	29.1
2001EX9800	$2.88 ($6.35)	$3,651,140	29.0
2001SM00	$2.86 ($6.31)	$3,534,661	28.0
2001SM9800	$2.85 ($6.28)	$3,487,451	27.6

Source: Processor interviews and PacFIN database.

The next step involved calculating each processor's weighted average price (WAP), which is the weighted average yield-adjusted price charged for final product forms sold by each processor.[15] Industry-wide weighted average price was estimated by multiplying each processor's WAP in our sample by their estimated share of statewide crab landings purchased. We then extrapolated the sample WAP (scenarios denoted by "EX"), or extrapolated the WAP for our small firm (scenarios denoted by "SM"), to get an industry-wide WAP.

Once the industry-wide WAP was estimated, value added for the crab-processing industry could then be estimated. The percent value added was calculated as (WAP—weighted average ex-vessel purchase price) divided by average ex-vessel purchase price provided in Didier (2002). The percent value added simply expresses processor value added per dollar of purchased crab. Industry-wide value added was then calculated by multiplying percent value added by the total cost of purchased crab landed in California (ex-vessel revenue).

The scenarios were also used in an equivalent manner to estimate the industry-wide mix of Dungeness crab product forms, their weighted average prices, and their percent value added for 2000 and 2001.

Estimates

For purposes of comparison, information on ex-vessel landings, revenue (value added), and price per pound is provided in Table 3. Crab fishers added nearly $18 million in value in the 1999–2000 season. In contrast, higher prices in 2000–2001 were not enough to compensate for reduced landings, and value added by crab fishers declined to a bit more than $12 million.

Estimates for WAP, value added, and percent value added for processors that purchased Dungeness crab landed in California in 2000 and 2001 are provided in Table 4.

[15]The weighting factor is simply the yield-adjusted share of the particular product form in the processor's overall product mix. Note that WAP multiplied by the pounds purchased by processors is equal to total gross processor revenue.

In terms of value added, there was little difference in the two scenarios ("EX" and "SM") used to estimate WAP, value added, and percent value added for 2000. In both cases the weighted average price per pound of the product forms was approximately $3 (or $6.62 per kilogram), industry-wide value added ranged from $8.45 to $8.83 million, and value added by processors is estimated to be 47.5% to nearly 50% of that added by crab fishers. It is interesting to note that prices, value added, and percent value added were all slightly lower in the "2000SM" scenario, which extrapolates information from the small processor in our sample to the out-of-sample processors, relative to the "2000EX" scenario. As will be described in greater detail below, this is because the fresh and live product forms add less value per pound than the frozen and picked-meat product forms.

The 2001 estimates for industry-wide value added were also relatively insensitive to scenario. In particular, industry-wide value added ranged from $3.49 million (scenario 2001SM9800) to $3.68 million (scenario 2001EX00), a difference of only 5.4%. As with the 2000 estimates, value added was lower in the "SM" scenarios relative to the "EX" scenarios in 2001. Value added by processors ranged from 27% to 29% of that added by crab fishers, which is substantially lower than the comparable estimates for 2000.

Several factors resulted in the decrease in total value added and percent value added in 2001 relative to 2000. First, note from Table 3 that weighted average ex-vessel price per pound was higher in 2001 ($2.02 in 2000 com-

TABLE 5
Industry-wide Percent Value Added by Dungeness Crab Product Form

	Percent Value Added				
Scenario	Frozen whole cooked	Frozen sections	Frozen picked meat	Fresh whole cooked	Live
2000EX	39.6	53.6	73.5	28.5	38.6
2000SM	39.6	60.6	76.4	32.4	38.6
2001EX00	25.8	42.3	32.0	21.4	26.3
2001EX9800	26.1	43.3	31.8	20.8	26.2
2001SM00	35.6	51.9	32.1	18.9	26.3
2001SM9800	37.1	55.2	32.1	18.5	26.2

Source: Processor interviews and PacFIN database.

pared to $2.23 in 2001), likely because of the substantially lower landings in 2001 (in kilograms the respective numbers are $4.45 and $4.92). Second, note that the estimated industry-wide WAP of crab product forms was lower in 2001 across all scenarios. From Table 5 we can see that the percent value added declined for each product form in 2001 relative to 2000 across nearly all the scenarios. One possible explanation for this decline could be the worsening economy in the United States and the 9/11 tragedy in 2001, which reduced consumer confidence and vacation travel.[16]

In terms of the primary questions this study addresses, note that the percent value added by fresh and live product forms was generally less than that of the frozen and picked meat product forms. If consumers perceive fresh and live product forms as possessing superior quality to the frozen product forms (much of the picked meat product form originates from the secondary processing of previously frozen crab), then presumably this would be manifested in higher prices per pound for the fresh and live product forms, especially if the pulse of landings suppresses this product form.[17] In fact, our analysis suggests that this is not the case. Since estimated percent value added by product forms in Table 5 relates the yield-adjusted sales price to a given dollar of purchase cost, it is evident that the frozen (and picked meat) product forms featured higher yield-adjusted prices per pound. From Table 6 we can see that under most scenarios only about half of the Dungeness crab landed in California is processed into fresh or live product forms.[18]

The superior yield-adjusted price for picked meat products might be explained by the notion that many final consumers (e.g., diners at restaurants and on cruise ships) value convenience over freshness, since picking meat from a Dungeness crab is a somewhat laborious task.[19] In fact, our estimates for percent value added in 2000 are consistent with the picked meat product having the highest yield-adjusted value in the marketplace (though this was less evident in the 2001 estimates). Processors in our interviews noted the importance of maintaining restaurant, cruise ship, and other food service accounts that serve as key market channels for picked meat. The importance of maintaining these picked meat market channels is indicated by trends in the estimated share of total statewide Dungeness crab landings going into the picked meat product form. Note that the percentage of crab processed into a picked meat product generally increased in 2001, when landings had decreased, indicating the importance of protecting market channels for picked meat.

Recall that the literature cited earlier suggests that derby fisheries result in substantial unmet consumer demand for fresh finfish. The superior market value of fresh finfish product forms over frozen product forms served as the foundation for improved economic conditions in the relevant fisheries when IQ management systems were utilized. While our analysis can only conjecture about the changes in product forms that might occur as a result of temporally distributing the current pulse of Dungeness crab landings, the higher yield-adjusted market value of frozen and picked meat product forms suggests that the economic benefits may be smaller for crab than have been observed for finfish.

Comparing the scenarios that emphasize the characteristics of small processors (scenarios designated by "SM") with those based on an extrapolation of the overall sample (scenarios designated by "EX") in Table 6 sheds light on the different product form strategies pursued by small and large processors. Our small processor scenarios indicate a focus on fresh "whole cooked" crabs, though, interestingly, large processors appear to produce the larger proportion of the live crab product form.[20]

[16]San Francisco, for example, experienced a significant loss of tourist visitation following 9/11, and news reports at the time indicated proportionately lower sales of Dungeness crab and other seafood.

[17]Connoisseurs of Dungeness crab who advocate for superiority of fresh and live crab might argue that this is a consumer education issue and a shortcoming of current marketing efforts.

[18]By way of comparison, Radtke and Davis (2000) estimated that roughly 25% of Dungeness crab in 1996 was processed into a "fresh whole cooked" product form, with the remainder processed into picked meat or frozen sections. Evidently the live crab market is relatively recent.

[19]Given the regional nature of the market for fresh crab and the perishability of this product, lower prices may also be required in order to sell fresh crab quickly.

[20]Several of the large processors in our survey noted that they had made efforts to penetrate the live crab market in recent years.

TABLE 6
Industry-wide Estimated Dungeness Crab Product Mix (percentages)

Estimate scenario	Frozen whole cooked	Frozen sections	Picked meat	Fresh whole cooked	Live
2000EX	3.8	12.3	30.4	21.9	27.2
2000SM	2.6	11.7	22.2	42.1	18.6
2001EX00	4.6	6.6	48.3	19.2	21.4
2001EX9800	4.9	5.9	50.5	20.4	18.3
2001SM00	5.9	7.2	35.4	37	14.6
2001SM9800	6.3	6.9	33.8	41.8	11.2

Source: Processor interviews and PacFIN database.

TABLE 7
2001 California Dungeness Crab Processing Employment and Capital Stock Estimates

Scenario	Peak employment	Off-peak annual employment	Capital stock
2001EX00	485	142	$6,070,475
2001EX9800	506	146	$6,246,654
2001SM00	530	97	$4,291,782
2001SM9800	552	89	$3,995,356

Source: Processor interviews and PacFIN database.

We were only able to get sufficient information on employment and capital stock from our survey to develop industry-wide estimates for 2001, as illustrated in Table 7. As before, industry-wide estimates were found by extrapolating in-sample employment and capital stock to out-of-sample processors. Note that in 2001 the peak employment estimate ranges from 485 to 552 (during the weeks when the pulse of landings is being processed), depending on scenario, whereas the off-peak "year-round" industry-wide employment (mostly picking lines) estimate ranges from 88 to 142. Note the distinctive employment signatures of small and large processors. Large processors cause the "EX" scenarios to estimate a larger off-peak level of employment than the "SM" scenarios. In contrast, the greater emphasis on small processors in the "SM" scenarios results in a higher estimate for peak season employment. A likely explanation is that large processors, which produce proportionately more picked meat, operate picking lines throughout the year, whereas small processors produce proportionately more fresh "whole cooked" crab sold during the holiday season.

Capital stock is also clearly a marker of large processors.[21] The "SM" scenarios lead to capital stock estimates of around $4 million, whereas the "EX" scenarios lead to capital stock estimates of around $6 million. Clearly this difference reflects the added expense of large freezer capacity held by large processors.

CONCLUSION

Our analysis estimates that picked meat and frozen crab product forms elicit the highest yield-adjusted market prices and value added under the current fishery management system. By freezing crab sections for picking later, the larger processors are able to manage the flow of product into the market, in sharp contrast to the large pulse of fresh crab landed in the season's first weeks. The share of landed crab being processed into picked meat increased when overall landings decreased, which supports the importance asserted by processors we interviewed of protecting market channels for picked meat during years with poor landings. Our findings were somewhat surprising because analysis from finfish fisheries indicates that fresh product forms tend to carry a higher consumer valuation than frozen product forms. We conjecture that many final consumers value the convenience of picked crab over fresh or live crab. These findings suggest that the shift to higher-value product forms resulting from the temporal distribution of landings in finfish fisheries may not necessarily occur if the current derby fishery for Dungeness crab were eliminated.

We hasten to observe that these findings are only suggestive, and that fishery management that expands the temporal distribution of landings significantly (such as through IQs) could generate a variety of benefits. These benefits may include improved safety, less incentive to overcapitalize, and stronger incentives for product innovation and marketing efforts. Over time the latter could very well change relative consumer preferences for different Dungeness crab product forms.

Most of the processors interviewed for this report consider Dungeness crab to be a seasonal or luxury food item associated with various celebratory events, with peak consumption of fresh crab products occurring between Thanksgiving and New Year's Day. Processors noted difficulty in moving fresh crab after late January (Super Bowl weekend). The fact that peak consumption of fresh Dungeness crab occurs during the holiday season, which corresponds to the only time in recent years that fresh product is available, suggests that consumer demand may be adaptable to seasonable availability.

The large processors in our survey mentioned that target frozen inventory levels are usually set prior to the season based on existing inventory and projected consumer demand. Processors base their estimate of future

[21]Note that "capital stock" refers to processing facilities, equipment, and inventory, and is not specific to crab.

consumer demand on overall economic indicators (economic growth, consumer confidence) and the price and availability of substitutes. Key substitutes were reported to be Dungeness crab products out of Washington, Oregon, and British Columbia, snow crab products, and more generally other seafood and meat products. As the season begins and it becomes clear that their target inventory level will be reached, then production shifts to include fresh and live product forms. Processors noted that fresh product is easier to unload quickly. In years with low landings, large processors focus most of their production on frozen products, leaving more of the fresh and live market to smaller processors.

The processors interviewed for this study report considerable difficulty in moving large quantities of fresh crab product forms outside of the region due to the cyclical nature of the fishery. In years with large landings, the industry is able to develop new markets, such as East Coast restaurant accounts. These processors report high product satisfaction in these new markets. But then when years with very small landings come along, processors report that rising ex-vessel prices put upward pressure on fresh product form prices, and out-of-region markets are more price sensitive than those within the region due to reduced product identity. Processors claim that this price sensitivity effectively eliminates fresh Dungeness crab products from being regular restaurant menu items outside of the region.

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