California Agriculture

Volume 58, *Number* 4 2004 *Page* 186

Racing for crabs . . . Costs and management options evaluated in Dungeness crab fishery

Christopher M. Dewees Kristen Sortais Matthew J. Krachey
Steven C. Hackett David G. Hankin

Abstract

Dungeness crab support a valuable commercial fishery in California, yet in recent decades the fishery has intensified significantly, with most crab landed during the first 6 weeks of the 7-month season. This study of fishermen's operating costs and their opinions of new management measures is intended to support discussions and decision-making about policy changes that may affect the economics of the fishery. Our survey results show that a majority of fishermen have favorable views of only two of 12 alternative measures (one trap-limit for all size vessels and daylight-only fishing). However, opinions of these measures vary between owners of different-sized vessels. Experiences in other crustacean trap fisheries around the world suggest that simply implementing these two measures may not significantly decrease total trap numbers fished or slow the race for crab.

Keywords: Dungeness crab, fishery management, Sea Grant, extension, commercial fishing, marine, trap, regulation, Cancer magister

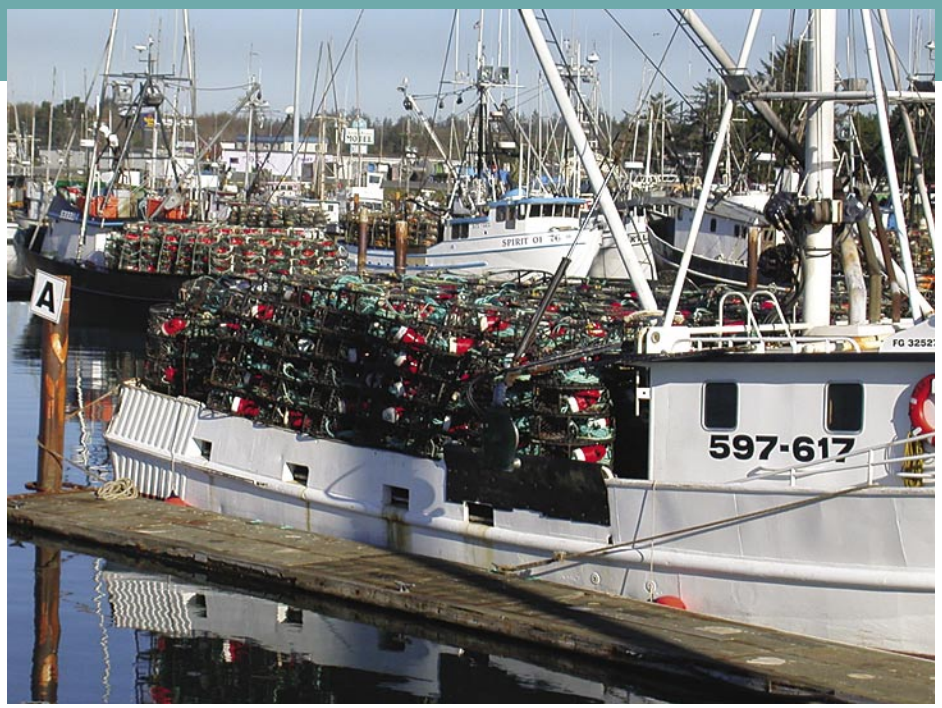
Suggested Citation:
Christopher M. Dewees, Kristen Sortais, Matthew J. Krachey, Steven C. Hackett, and David G. Hankin (2004) "Racing for crabs . . . Costs and management options evaluated in Dungeness crab fishery", *California Agriculture*: Vol. 58: No. 4, Page 186.
http://repositories.cdlib.org/anrcs/californiaagriculture/v58/n4/p186

Racing for crabs . . .

Costs and management options evaluated in Dungeness crab fishery

Christopher M. Dewees
Kristen Sortais
Matthew J. Krachey
Steven C. Hackett
David G. Hankin

Dungeness crab support a valuable commercial fishery in California, yet in recent decades the fishery has intensified significantly, with most crab landed during the first 6 weeks of the 7-month season. This study of fishermen's operating costs and their opinions of new management measures is intended to support discussions and decision-making about policy changes that may affect the economics of the fishery. Our survey results show that a majority of fishermen have favorable views of only two of 12 alternative measures (one trap-limit for all size vessels and daylight-only fishing). However, opinions of these measures vary between owners of different-sized vessels. Experiences in other crustacean trap fisheries around the world suggest that simply implementing these two measures may not significantly decrease total trap numbers fished or slow the race for crab.



The Pacific Coast's commercial Dungeness crab fishery pulls in between $32 million and $84 million annually, with crab abundance peaking in approximately 10-year cycles. While the catch has been sustainable, in recent years 80% of landings have been made in the first full month of the season (December). Crab boats are loaded with traps in Crescent City, Calif., before the season opens.

Dungeness crab range from Santa Barbara to Alaska's Aleutian Islands. Commercial landings fluctuate widely each winter, but consistently rank as one of the most valuable Pacific Coast fisheries. From the 1990-1991 season (generally December through June) through the 2000-2001 season, combined landings for California, Oregon and Washington averaged 32.8 million pounds, worth between $31.7 million to $84.4 million annually to fishermen (Didier 2002).

California's Dungeness crab *(Cancer magister)* fishery began in the San Francisco area about 1848 and expanded northward after World War II. The fishery has long been intense and highly competitive. On Dec. 11, 1949, a *Humboldt Times* headline reported, "Three Crescent City fishermen beaten in San Francisco crab war . . . Bay Area men ired at northern poachers."

California landings have been highly variable, ranging from a low of 350,000 pounds in 1973-1974 to more than 30 million pounds in 1977-1978 (Hankin and Warner 2001). A small but growing recreational fishery is believed to take less than 1% of the harvest. Peaks in abundance appear to occur in approximately 10-year cycles.

The fishery has been fully and intensely exploited for at least 40 years. Approximately 80% to 90% of the legal-sized male crabs are harvested each season. Despite this intense harvest and high variability in abundance, most scientists and industry participants feel that current regulations are adequately protecting the crab resource (Hankin and Warner 2001). These regulations include a 1995 cap on the number of vessels allowed to harvest Dungeness crab in California waters, a 6.25-inch minimum harvest size for male crabs, approximately 5 months annual closure to harvesting, no take of female crabs, and mandated escape openings on traps for undersize crabs. California's seafood industry has appreciated what appears to be a sustainable and valuable harvest of Dungeness crabs at a time when other major fisheries such as rockfish and salmon have declined significantly.

Yet juxtaposing the sustainability of crab stocks is the fishermen's intensifying yearly race for crab. In recent decades, the increasing number of vessels and intensity of their participation has led to a race for crabs. Though landings have come primarily during winter months since at least 1950, before 1980 the crab season was spread from December to July. In recent years, approximately 80% of the landings are made in December (Hankin and Warner

The fishermen's intense race has led to glutted markets, increased densities of crab traps on the fishing grounds, and fishing in dangerous conditions leading to loss of lives and vessels.

2001). The fishermen's intense race has led to glutted markets, increased densities of crab traps on the fishing grounds, and fishing in dangerous conditions leading to loss of lives and vessels.

In 1995, the crab industry and the California Department of Fish and Game (DFG) began to address the harvesting over-capacity with legislation mandating a moratorium on the issuing of more permits for vessels to harvest Dungeness crab. While this restricted the number of vessels to about 600, it did nothing to limit the amount of fishing effort (time, traps, vessel size, horsepower) used by these participants. Reduced opportunities in other fisheries, especially those targeting rockfish and other groundfish, have increased fishing effort directed at crab.

For years, fishermen have discussed spreading harvests more evenly through the season, but have come to no agreements. To contribute to this discussion, we surveyed California Dungeness crab fishermen to gather basic demographic and economic data and to measure their opinions on current and potential fishery management measures. Our research is intended to provide an information base from which industry may decide what next steps (if any) they wish to take.

Survey of crab fishermen

Our first step was to review regulatory management tools used in other crustacean trap fisheries around the world via a literature review and contacts with fishery managers (see box). Most of these management tools address issues related to over-capacity in fishing fleets and slowing the pace of harvest. We provided this information to fishermen with our mail survey questionnaire.

Our primary research tool was a six-page mail survey sent to the 616 individuals who purchased California commercial Dungeness crab vessel permits for 2001. We designed our survey based on Dillman (2000). We asked permit holders about characteristics of their fishing business, crab fishing costs, revenues and effort, their opinions of the current management system and their opinions of 12 potential management tools (contact first author for a copy of the questionnaire). We asked fishermen to rank their responses to each management tool on a five-point Likert scale (strongly unfavorable to strongly favorable). The survey concluded by giving respondents an opportunity to describe their vision of the best system for managing California's Dungeness crab fishery.

Given widespread wariness among fishermen that research might lead to new regulations that would hurt their operations, we actively conducted pre-survey outreach. We met with focus groups of 2 to 25 crab fishermen at four major ports (Crescent City, Eureka, Noyo and Bodega Bay) and at a California Salmon Council meeting in Sacramento. At these meetings we distributed summaries of crustacean management tools in use internationally, attempted to assuage fears about participation in the project, answered questions, asked for advice on increasing response rates, and pre-tested and received feedback on draft surveys.

After multiple revisions and two pre-tests, we mailed our final survey in November 2002. We sent only one survey to the 27 fishermen we could identify as owning multiple California crab permits. Two weeks after mailing the surveys, we sent a follow-up postcard to all permit holders as a reminder and offered a replacement survey if necessary.

Seven surveys were returned as undeliverable and 243 were returned completed, a response rate of 40%. We believe our sample is generally representative of the total crab fleet. Survey respondents generally reflect the home-port distribution of all permit holders (table 1).

Regulatory management tools

Daylight-only fishing: Harvest is permitted during daylight hours only.

Individual fishing quotas (IFQ): Allocates a portion of the total allowable catch (TAC) to individual vessels based on agreed-upon criteria such as catch history or vessel characteristics. IFQs can include: (1) **individual transferable fishing quotas,** which can be sold or leased (either freely or within agreed-upon constraints) among fishery participants; (2) **individual fishing quotas**, which are not transferable; (3) **community quotas,** in which part or all of the total allowable catch is allocated to a community or group of associated individuals to allocate locally among fishery participants.

One trap-haul (pull) per day: Hauling gear to the surface is permitted once per day.

Regional/area/zonal management: Management differs between locations (for example, seasons, trap limits and total allowable catches differ by locale).

Trap certificates: Allow individual fishermen to use a certain number of traps for the season. Each certificate represents one trap. Trap certificates can be: (1) **transferable,** in which a portion of an overall trap total is allocated to fishermen and can be sold or leased in or out (either freely or within agreed-upon constraints); or (2) **nontransferable,** allowing fishermen to choose a tier within a per-vessel maximum trap limit.

Trap limits: Establishes the maximum number of traps a vessel can fish. They can be: (1) **one maximum,** which applies to all vessels regardless of vessel size; (2) **multi-tier,** with several different maximum limits for different-size vessels or other criteria; (3) **graduated,** which change over the season (for example, increasing as crab abundance declines or as the season goes on).

Trip limits: Limits the landings that individual vessels can make per trip.

TABLE 1. Home-port distribution of vessels with California Dungeness crab vessel permits compared with home-port distribution of survey respondents

City	Respondents	Permitted vessels
	% (*n*)	%
Crescent City	19.5 (46)	20.0
Trinidad	4.8 (11)	3.9
Eureka	14.0 (33)	11.6
Fort Bragg	13.1 (31)	8.8
Bodega Bay	12.3 (29)	11.3
San Francisco	6.8 (16)	13.6
Half Moon Bay	11.4 (27)	8.9
Santa Cruz	1.7 (4)	2.1
Moss Landing	0.4 (1)	1.8
Morro Bay	1.7 (4)	1.1
Avila Beach	1.8 (3)	1.3
Other CA ports	4.8 (11)	6.1
Oregon ports	8.7 (20)	9.6

Source: California Department of Fish and Game license data (April 2003).

TABLE 2. Characteristics of individuals with California Dungeness crab vessel permits (number of respondents)

	n
Length of primary crab fishing vessel	
Small: < 30 feet	35
Medium: 30–50 feet	137
Large: > 50 feet	63
Tenure in fishery	
0 to ≤ 9 years	42
> 9 to ≤ 19 years	61
> 19 to ≤ 29 years	77
> 29 years	56
% of gross income from Dungeness crab fishing, 2002	
≤ 20%	17
> 20% to ≤ 40%	46
> 40% to ≤ 60%	66
> 60% to ≤ 80%	83
> 80% to 100%	23
Mean number of days fishing Dungeness crab, 1998–2000	
≤ 50 days	32
> 50 to ≤100 days	53
> 100 to ≤ 150 days	62
> 150 to ≤ 200 days	50
> 200 days	19
Mean number of traps fished, 1998–2000	
≤ 200 traps	67
> 200 to ≤ 400 traps	96
> 400 to ≤ 600 traps	40
> 600 traps	21

Fleet characteristics, costs

When compared to DFG permit data, our sample contained a similar proportion of owners of vessels under 30 feet (14.9% versus 15.4%). Medium vessels are slightly under-represented (58.6% versus 70.8%), and vessels over 50 feet (which tend to be the largest producers) are over-represented (26.8% versus 13.8%)(table 2). The majority of survey respondents own medium vessels and about half have at least 20 years of experience fishing crab. About 75% fish with fewer than 400 traps.

Trap deployment. By looking more closely at trap usage, we found that during the 2000-2001 season fishermen deployed an average of 293 traps per vessel during the peak fishing month of December. On average during December, small, medium and large vessels fished 138, 259 and 448 traps each, respectively. Trap numbers increased substantially with vessel size, reflecting increasing capability to carry traps. During the first month or two of the season traps were usually hauled daily. As crab density and catch rates declined, traps were often pulled at 48- to 72-hour intervals. Fishermen will move their traps to different areas or depths in search of improved catch rates.

By extrapolating the mean number of traps by vessel size fished by respondents, to the total number of permit owners by vessel size, we estimate that 171,090 traps were deployed in California's crab fishery in December 2000. This compares with estimates of 146,978 and 64,806 traps in Oregon and Washington during the same time period (Didier 2002). While we are not aware of any other estimates of California trap numbers since the 1975-1976 season, Didier estimated that from 1971-1972 through 1975-1976 California trap numbers averaged 29,115. During the same period Oregon and Washington trap estimates were 52,380 and 35,840, respectively. It seems clear that the amount of fishing gear in California waters has increased significantly since 1975-1976.

Other fisheries. Dungeness crab fishing is just one of several fisheries that fishermen utilize during the year. Salmon, albacore tuna, groundfish, pink shrimp, sea urchin and live fish were often mentioned in the diverse mix of target species. We were surprised at the relative importance of crab to respondents; 73% indicated that more than 40% of their gross income came from fishing Dungeness crab (table 2). For those with vessels less than 30 feet, crab fishing appears to be a relatively minor component of their incomes.

Value of permits. When we asked fishermen to estimate the value of their crab permit, estimates increased with vessel size. On average, owners of small, medium and large vessels estimated their permit value at $10,303, $18,187 and $31,111, respectively (roughly $500 per foot of vessel length). Larger vessels are able to load, move and fish more traps. They can also better handle the dangerous winter weather conditions and are more likely to be able to fish day and night. In addition, some of the larger vessels can hold large quantities of crab in live wells onboard, enabling them to take multiday trips.

Fishing costs. As average trap usage increases by vessel size, so do annual and daily variable costs attributed to crab fishing (table 3). Gear repair primarily involves replacement of lost or worn-out traps, while trap storage costs occur in the off-season. Crewmembers are typically paid a percentage of the landings proceeds, reflecting traditions of crew motivation and sharing risk. Crew costs increase with vessel size because larger vessels often require two deckhands to handle the larger number

TABLE 3. Mean Dungeness crab fishing costs of survey respondents, by vessel size

	Annual costs		Daily costs		Other	
Vessel size	Gear repair	Trap storage	Bait	Fuel	Variable costs	Crew share
			$ (SD*)			%
Small: < 30 feet	2,239 (1,932)	149 (228)	57 (63)	41 (44)	40 (54)	15 (10)
Medium: 30–50 feet	4,006 (3,259)	626 (936)	155 (233)	68 (137)	41 (52)	24 (11)
Large: > 50 feet	6,656 (4,072)	1,650 (2,237)	226 (163)	150 (83)	62 (29)	31 (10)

* Standard deviation.

TABLE 4. Opinions of Dungeness crab survey respondents on proposed management tools

Management tools (n)	Strongly fav.* or fav.	Neutral	Strongly unfav. or unfav.	Mean score (SD)†
	..... *n*			
Current management system (198)	153	19	26	4.11 (1.18)
One trap-limit for all size vessels (196)	138	9	49	3.85 (1.63)
Daylight-only fishing (222)	143	15	64	3.59 (1.67)
Transferable trap certificates (188)	72	17	99	2.68 (1.74)
Nontransferable trap certificates (168)	61	16	91	2.67 (1.72)
Trip limits (186)	67	17	102	2.60 (1.67)
Different trap limits for different-size vessels (187)	72	9	106	2.60 (1.66)
One trap-haul per day (211)	62	36	113	2.59 (1.60)
Regional/area/zonal management (206)	69	23	114	2.54 (1.64)
Transferable IFQs‡ (197)	45	16	136	2.08 (1.34)
Nontransferable IFQs (190)	26	15	149	1.80 (1.53)
Community quotas (205)	20	14	171	1.62 (1.14)
Graduated trap limits (148)	9	23	116	1.61 (0.98)

* Favorable.

† Scale: 1 = strongly unfavorable, 2 = unfavorable, 3 = neutral, 4 = favorable, 5 = strongly favorable. (Standard deviation.)

‡ Individual fishing quotas.

of traps hauled each day, whereas small vessels usually have just one deckhand in addition to the skipper.

Views on management tools

The heart of our research was our analysis of fishermen's opinions of management tools. Opinions generally fell into three tiers (table 4). The majority of respondents expressed a favorable or strongly favorable opinion of only three tools: the current management system, one trap-limit for all size vessels and daylight-only fishing. The current management system consists primarily of regulations designed to sustain crab populations, whereas the 12 other management tools relate to vessel operations, economics and allocation of the catch.

The large majority of respondents approved of one trap-limit for all vessels rather than having trap limits based on vessel size. There was little support for limiting overall statewide trap numbers by issuing transferable or nontransferable trap certificates to individual vessels. Fishermen expressed almost no support for increasing trap limits during the season as crab densities on the fishing grounds decline.

A majority of respondents also supported confining fishing to daylight hours. This measure would limit the number of traps that could be pulled on a single day. Currently some vessels, primarily larger ones, operate 24 hours a day and are able to fish more traps. Allowing only one pull of traps per day received little support. Respondents expressed concerns about the ability to enforce this regulation short of onboard video cameras.

The use of harvest-rights systems such as individual or community quotas, which have been used elsewhere to slow the race for fish and shellfish, garnered little support. Respondents mentioned concerns about aggregation of harvest rights in the hands of a few and DFG's lack of ability to determine annual quotas as barriers to implementation of these types of quota systems.

Finally, only a minority favored managing the fishery with differing regulations in different zones, even though there are currently different season opening and closing dates in Northern and central California.

Vessel size & management opinions

In discussions at our five pre-survey focus-group meetings and with fishery managers, we found that much of the historical and current disagreement over alternative management approaches has been among participants with different-sized vessels. Industry discussions about trap limits and zonal management have broken down over differences between owners of large as compared to medium and small vessels. For this reason we decided to take a closer look at the differences in opinions of management tools based on vessel size categories (vessel size is also highly correlated with number of traps used, percentage income from crab fishing and number of days fishing for crab annually). Vessels were divided into three length categories: less than 30 feet (small), 30 to 50 feet (medium) and larger than 50 feet (large). These categories are the same as those used by the Pacific States Marine Fisheries Commission in their analyses of California, Oregon and Washington Dungeness crab fisheries (PSMFC 1993).

We tested the null hypothesis that opinions regarding the 13 management tools do not differ among vessel size categories (small, medium and large). We first used a Kruskal-Wallis test (Hays 1988) to determine if there were significant differences in opinions. When the Kruskal-Wallis test indicated significant differences among categories, we then used the Kolmogorov-Smirnov test to make specific pair-wise comparisons across vessel size categories. To test whether difference exists in the mean response across two categories, a randomization test based on Manly (1997) and written by the authors was used. We report the mean *P* value of the 10,000 simulations here.

Using the Kruskal-Wallis test, we rejected the null hypothesis that respondent opinions are the same across the vessel size categories for five alternative management tools (table 5). Generally, as vessel size increases, support decreases for one trap-limit for all size vessels, trip limits, community quotas, regional management and daylight-only fishing. When we tested for pair-wise differences between specific size categories, large vessel owners' opinions were significantly different from both medium and small vessel owners on all five management tools. Differences between small and medium vessel owners' opinions differed only on regional management.

Implications for the fishery

Though the pace of Dungeness crab fishing has continued to intensify, it remains a profitable and important fishery. Crab processors have evolved strategies to deal with the huge early-season pulse of crab landings (see sidebar, page 190). At the same time, fishermen continue to struggle to find ways to cope rationally with the increasing intensity of the crab harvest.

Race for Dungeness crab influences processing, markets

Steven C. Hackett
Christopher M. Dewees
Matthew J. Krachey

About half of the Dungeness crab catch is sold fresh or live, while the rest is frozen or processed into picked meat. This crab has two red tags; cooperating commercial fishermen return the tags so that researchers can estimate crab movements and collect other data.

In recent decades the California Dungeness crab fishery has experienced a race for crabs, or derby, where approximately 80% to 90% of annual seasonal landings occur between late November and the end of December. Some processors have responded by developing large-scale processing and freezing capacity that can accommodate the pulse of crab landings and be used for processing other fish species at other times of the year. The combination of large-scale processing and declines in the groundfish and salmon fisheries has resulted in a more consolidated processing industry structure that features a small number of large processing firms.

Baseline economic information was collected on this processing sector in California for two Dungeness crab fishing seasons, 1999-2000 and 2000-2001 (Hackett et al. 2003). Our research methodology involved the use of confidential fish-ticket data from the California Department of Fish and Game, and interviews with key informants at six processing firms. These firms, located in California and southern Oregon, purchased 60% of the crab landed in California in 1999-2000. We found that:

- The estimated average wholesale price of various Dungeness crab products (adjusted for yield rates from the live crab) in 1999-2000 was approximately $3 per pound.
- The estimated value added by processors ranged from $8.45 million to $8.83 million. Value added by processors is measured as processed-crab sales revenue less the cost of crab purchased from fishermen, whereas value added by fishermen is measured as revenue received by fishermen for selling crab to processors.
- The estimated value added by processors ranged from 47.5% to nearly 50% of that added by crab fishermen.
- The value added by fresh and live products (based on yield-adjusted prices expressed as a percentage of the ex-vessel value) was generally less than that of the frozen and picked-meat products.

Prices. If fresh and live product are perceived by consumers as possessing superior quality to that of the frozen product (much of the picked meat 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, especially if the pulse of landings suppresses this product. In fact, our analysis suggests that this was not the case — the frozen and picked meat featured higher yield-adjusted prices per pound than those of fresh and live product. Our estimates indicate that only about one-half of the Dungeness crab landed in California was processed into fresh or live product during the 1999-2000 and 2000-2001 seasons.

Value of picked meat. The superior yield-adjusted price for picked-meat product could be explained by the notion that many final consumers (such as diners at restaurants and on cruise ships) value convenience over freshness, since picking meat from a Dungeness crab is a somewhat laborious task. In fact, our estimates for percentage value added in 1999-2000 are consistent with the picked-meat product having the highest yield-adjusted value in the marketplace (though this was somewhat less evident in the 2000-2001 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. 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.

Employment. Hackett et al. (2003) were only able to get sufficient information on employment and capital stock in Dungeness crab processing from surveys to develop industry-wide estimates for the 2000-2001 season. Estimated total peak crab-processing employment in 2000-2001 ranged between 485 and 552 people during the weeks when the pulse of Dungeness crab landings is being processed. In contrast, off-peak "year-round" industry-wide employment (mostly picking lines) was estimated to range between 88 and 142 people.

Luxury/special occasion food. Most of the processors surveyed consider Dungeness crab to be a seasonal or a luxury food associated with celebratory events, with peak consumption of fresh crab occurring between Thanksgiving and New Years Day. Processors noted difficulty in moving fresh crab after late January (Super Bowl weekend). Because fresh or live crab is difficult for consumers to locate after late January, it is impossible to judge whether consumer demand would increase if it were available for longer.

There is certainly substantial demand for the live product during the holiday season when it is available.

Frozen product. The large processors mentioned that target inventory levels for frozen crab are usually set prior to the season based on existing inventory and projected consumer demand. Processors base their demand estimates 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 target inventory levels will be reached, production shifts to include fresh and live product. 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.

New markets. The processors interviewed reported considerable difficulty in moving large quantities of fresh crab product 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 restaurants. These processors report high product satisfaction in these new markets. But when years with small landings come along, processors report that rising ex-vessel prices put upward pressure on fresh product 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.

David G. Hankin and Kristen Sortais contributed helpful review of this sidebar.

Reference

Hackett SC, Krachey MJ, Dewees CM, et al. 2003. An economic overview of Dungeness crab *(Cancer magister)* processing in California. CalCOFI Report 44:86–93.

TABLE 5. Opinions* of survey respondents on crab management tools, by vessel size category

	Vessel size		
Management tools	Small < 30 ft.	Medium 30 to 50 ft.	Large > 50 ft.
Current management system	4.3	4.1	3.9
One trap-limit for all size vessels†	4.1§	4.3§	2.8
Daylight-only fishing†	4.5§	3.8§	2.6
Transferable trap certificates	2.8	2.6	2.6
Nontransferable trap certificates	2.3	2.9	2.5
Trip limits‡	3.1	2.7§	2.1
Different trap limits for different-size vessels	3.1	2.3	3.0
One trap-haul per day	2.9	2.7	2.2
Regional/area/zonal management†	3.3§#	2.7§	1.7
Transferable IFQs**	1.9	2.0	2.3
Nontransferable IFQs	2.2	1.7	1.7
Community quotas†	2.2§	1.7§	1.1
Graduated trap limits	1.8	1.7	1.3

* Scale: 5 = strongly favorable, 4 = favorable, 3 = neutral, 2 = unfavorable, 1 = strongly unfavorable.
† Vessel size categories significant, Kruskal-Wallis test, $P = 0.01$.
‡ Vessel size categories significant, Kruskal-Wallis test, $P = 0.05$.
§ Significantly different from large vessels, Kolmogorov-Smirnov test, $P = 0.01$.
¶ Significantly different from large vessels, Kolmogorov-Smirnov test, $P = 0.05$.
# Significantly different from medium vessels, Kolmogorov-Smirnov test, $P = 0.05$.
**Individual fishing quotas.

There is widespread approval among fishermen of the current crab-management regulations based on traditional fishery management tools with seasons. However, when additional regulations are considered that affect fishing operations, opinions become highly polarized or negative.

Trap limits. The great increase in the number of traps fished and the accelerating pace of the fishery has led to years of discussion about whether to limit the number of traps each vessel may fish. On Sept. 23, Governor Schwarzenegger vetoed a bill that would have established a limit of 250 traps per vessel south of Point Arena, on an experimental basis. Our study showed that the majority of the fleet, with the exception of the large vessel owners, viewed trap limits favorably. Many of those survey respondents who oppose trap limits stated that they viewed it as a reallocation of crab to smaller operators. They saw this as a restriction of their business that was unjustified in terms of resource conservation.

We anticipate that trap limits would at best cap the total number of traps near current levels and prevent large increases in fishing effort. After implementation of trap limits in Maine's lobster fishery, the total number of traps fished increased (Acheson 2001). While the relatively few lobstermen above the trap limit reduced their operations, many of those under the limit increased their trap numbers toward the limit. Depending on the level set for trap limits, California's outcome could be similar. One alternative approach would be to scale trap limits to vessel length. However, the fleet did not rank this option favorably (table 4). California should also examine the early outcomes from trap-limit systems recently implemented in Washington state. Inside Puget Sound, trap limits are set at 100 per vessel and there are six harvest regions. Along the Pacific Coast there are trap tiers ranging from 350 to 500 traps per vessel based on catch history (personal communication, L. Veneroso, Shellfish Policy Leader, Washington Dept. of Fish and Wildlife).

If the industry wants to significantly reduce the total amount of gear in the water, additional measures that "ratchet down" the trap limit may be necessary. Some form of trap certificates, similar to those implemented in the Georgia blue crab and Florida spiny lobster fisheries (CFAC 1997; Larken and Milon 2000) might eventually need to be considered. Such a system would involve setting a total number of traps to be used by the fleet and issuing certificates (one per trap) to be placed on each trap by fishermen. The number of certificates could be reduced each year until the desired fleet-wide total is reached. Certificate transferability and geographic specificity could also be included.

Some form of trap limits is the alternative management tool most likely to be implemented because of the high level of approval among fishermen. Trap

California Dungeness crab fishermen were surveyed about new management measures to distribute the catch more evenly throughout the season. The majority — except large vessel owners — support the establishment of limits on the number of traps per vessel. Commercial fisherman James Gullett and Humboldt State University student Aaron Bliesner pull traps on the Humboldt County coast.

limits may be implemented together with other restrictions such as daylight-only fishing and trap limits that differ between central and Northern California. The recently implemented buyback of trawlers (December 2003) administered by the National Marine Fisheries Service (NMFS) included 23 large vessels that also fished for crab in California (U.S. Congress 2003). Fishermen remaining in the trawl, pink shrimp and Dungeness crab fisheries will repay about 80% of the cost of this buyback to NMFS. This 27% reduction in large vessels that fish crab may change the dynamics of industry discussions about trap limits.

Quota systems. Quota systems would assign specified harvest rights for a proportion of the total allowable catch to individuals or communities. They are generally perceived unfavorably by all sectors of the crab industry. In theory and in practice, however, these harvest-rights systems create incentives that slow the race for fish and shellfish and provide opportunities for innovative marketing to add value (Casey et al. 1995; NRC 2001); both results might improve the economic performance of the fishery. With assured access to a proportion of the total catch, quota holders could time their fishing and configure their fishing operation to maximize profitability. Some processors currently are able to do this to some degree by freezing crab harvested early in the season and then processing and selling the meat during the year to meet high-value demand by restaurants (see sidebar, page 190).

Survey respondents were concerned about the potential excessive aggregation of harvest rights and difficulties in making the accurate annual crab abundance estimates needed to set individual or community quotas. If quota systems were ever implemented, these concerns would have to be addressed. In addition, individual or community quotas would have to be specified geographically to be effective.

Given the current unfavorable opinion of quota systems, they are unlikely to be considered seriously in the near future even though they would likely slow the pace of the fishery. The Pacific Fishery Management Council's fall 2003 decision to examine individual fishing quotas for the groundfish trawl fishery could influence future knowledge and attitudes about quota systems in the crab fleet. The British Columbia (Canada) groundfish trawl fishery has operated profitably in recent years under an individual quota system. This has provoked a high level of awareness and interest from the U.S. Pacific Coast trawl fleet. The council conducted public scoping meetings on trawl fishery individual quota systems during summer 2004.

Regional or zonal management. Owners of larger vessels tend to view spatial management unfavorably. Their comments indicated a desire to move freely throughout the state to take advantage of the earlier season opening in central California as well as to maintain flexibility in their operations. Some fishermen would like to see trap limits only for central California and a uniform season opening date statewide. We feel that regional differences are likely to be part of any changes in crab management because crabs are usually more abundant in Northern California and the northern vessels, on average, are larger.

Daylight-only fishing and one trap-haul per day. These two management tools could be used to slow the fishery by reducing the fleet's fishing efficiency and harvest capacity. Not surprisingly, daylight-only fishing was significantly more popular with smaller vessel owners for whom night fishing is impractical and risky. Daylight-only fishing would reduce competition from large vessels that can fish many more traps, 24 hours per day, and in adverse weather conditions.

Where is the fishery headed?

This study clearly shows that the majority of the vessel owners favor some type of trap limits and some limitations on fishing at night. The larger, higher producers, who are fewer in number, tend to view further restrictions negatively, as hampering their ability to fully utilize their harvesting capacity. These decades-long differences in opinions due to vessel size continue to make management changes difficult.

The most likely near-term outcome is the adoption of some form of trap limits, at least on an experimental basis. The crab fishery in Washington recently adopted tiered trap limits and Oregon is seriously considering them. If Oregon implements trap limits, excess gear from Oregon could wind up being used in California and further intensify the fishery, pushing California toward trap limits.

Any trap-limit program should be closely evaluated after implementation. Other than preventing explosive growth in the amount of gear fished, a single level of trap limits (250 traps per vessel is proposed in current pending legislation) alone would likely have little effect on the overall fishery other than some transfer of catch from larger operations to smaller ones. As in many other common-pool natural resource

settings, the potential for redistribution of profits serves as a potent barrier to change (Hackett 1992).

If the fishermen's goal is to reduce the total amount of gear fished significantly below the current total of approximately 170,000 traps, some plan for systematically lowering total trap numbers will be needed. Some options include:

Trap certificates. Transferable or nontransferable certificates could be used that fit under an overall statewide or regional trap total. This total could be adjusted downward in an orderly fashion over the years to reach a generally acceptable number. Setting a target trap total(s) at the beginning of the process may help fishermen to accept the program.

Vessel trap limits. Limits could be set lower each season until reaching a target level. Larger vessels would likely oppose this approach. Trap limits could be scaled to vessel size.

Buy out. Those interested in leaving the fishery would receive a monetary payment similar to the recently implemented trawl-fleet buyback through a government loan. Those remaining in the fishery would reimburse the government over time. Some restrictions on traps would be needed to prevent excessive expansion by those remaining.

Harvest-rights system. Transferable or nontransferable rights would allocate a proportion of the overall allowable catch to each fisherman. This could slow the race for crabs and provide incentives for fishermen to make their individual businesses more efficient. It would require improved estimates of crab abundance, improved enforcement, quotas within geographic zones and agreed-upon quota aggregation limits.

Status quo. Let attrition under the current restricted-access program gradually reduce fleet size and perhaps the number of traps fished. This would likely take many years.

Trap limits appear to be the only alternative with a likelihood of adoption in the near term, but the long-term consequences of that approach are unclear.

Why haven't management tools used elsewhere in the world been seriously considered in California? It could be because trap limits have been considered and debated in great depth for many years. Fishermen, processors, DFG staff and key legislators have high awareness and knowledge about this approach compared to other alternatives.

Rogers (1995), in summarizing the large body of research about the adoption of new technologies and practices, demonstrates that people go through a series of stages in their process of adoption or rejection. Crab fishery participants are clearly well along in this process for trap limits and have developed perceptions of their relative advantages or disadvantages. However, many of these same participants have not been as focused on alternative management tools and are not as far along in the adoption/rejection process for them.

In addition, the California legislature — rather than the Pacific Fishery Management Council, DFG or the Fish and Game Commission — has primary responsibility for policy related to the Dungeness crab fishery. (The U.S. Congress transferred this authority to the individual state legislatures in 1996.) The long-term lack of industry consensus has made management changes by the legislature difficult in the past and is a likely barrier to alternative management approaches in the future, with the possible exception of some form of trap limits. If trap limits are adopted in the near future, but do little to solve perceived problems in the fishery, then it is possible that industry, fishery managers and the legislature will focus their attention on additional management options.

C.M. Dewees is Sea Grant Marine Fisheries Specialist, and K. Sortais is Research Associate, Department of Wildlife, Fish and Conservation Biology, UC Davis; M.J. Krachey is Graduate Student, and S.C. Hackett is Professor, Department of Economics, Humboldt State University; and D.G. Hankin is Professor, Department of Fisheries, Humboldt State University. *The authors acknowledge the 243 crab fishermen who generously shared their opinions and information about their business operations. We thank George Boos, Jack Carlson, Peter Leipzig, Chuck Wise and Richard Young for helping to set up project focus-group meetings and workshops in fishing ports. Thanks also to Janelle Kohl, California Sea Grant Extension Program, for her assistance with editing and layout. This research was supported in part by the National Sea Grant College Program of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration under NOAA Grant #NA06RG0142, project #R/F-187, through the California Sea Grant College Program, and in part by the California State Resources Agency. The views expressed herein do not necessarily reflect the views of any of those organizations.*

References

Acheson JM. 2001. Confounding the goals of management: Response of the Maine lobster industry to a trap limit. N Am J Fisheries Mgmt 21(2):404–16.

Casey KE, Dewees CM, Turris BR, Wilen JE. 1995. The effects of individual vessel quotas in the British Columbia halibut fishery. Marine Resource Econ 10(3):211–30.

[CFAC] Coastal Fisheries Advisory Commission. 1997. Georgia Blue Crab Fishery Management Plan. Blue Crab Issues Subcommittee. Georgia Department of Natural Resources. Brunswick, GA.

Didier AJ. 2002. The Pacific Coast Dungeness Crab Fishery. Pacific States Marine Fisheries Commission, Gladstone, OR. 30 p.

Dillman DA. 2000. *Mail and Internet Surveys: The Tailored Design Method* (2nd ed.). New York: J Wiley. 464 p.

Hackett SC. 1992. Heterogeneity and the provision of governance for common-pool resources. J Theoretic Politics 4(3):325–42.

Hankin DG, Warner RW. 2001. Dungeness crab. In: Leet WS, Dewees CM, Klingbeil R, Larson EJ (eds.). *California's Living Marine Resources: A Status Report*. Sacramento: California Dept. of Fish and Game. UC DANR Pub SG01-11. p 107–11.

Hays HL. 1988. *Statistics* (4th ed.). Orlando, FL: Holt Rinehart Winston. 1,029 p.

Larken SL, Milon JW. 2000. Tradable effort permits: A case study of the Florida spiny lobster trap certificate program. In: Proc Tenth Biennial Conf Int Inst Fisheries Econ Trade. http://oregonstate.edu/Dept/IIFET/2000/papers/larkin.pdf

Leet W, Dewees C, Haugen C. 1992. *California's Living Marine Resources and their Utilization*. California Sea Grant Extension Pub UCSGEP-92-12. Davis, CA. 257 p.

Manly BFJ. 1997. *Randomization, Bootstrap, and Monte Carlo Methods in Biology* (2nd ed.). London: Chapman Hall. 399 p.

[NRC] National Research Council. 1999. *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas*. Washington, DC: Nat Acad Pr. 422 p.

[PSMFC] Pacific States Marine Fisheries Commission. 1993. A review of the California, Oregon and Washington Dungeness crab fishery. Gladstone, OR.

Rogers EM. 1995. *Diffusion of Innovations* (4th ed.). New York: Free Pr. 519 p.

US Congress. 2003 (Nov. 4). Fed Reg 68(213):62435–8.