

Racing for crabs . . .

Costs and management options evaluated in Dungeness crab fishery

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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.

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



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.

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

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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 per-

mits 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

Vessel size	Annual costs		Daily costs		Other	
	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)†
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.