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ABSTRACT: A proposed vessel-specific pot limit for the Adak, Alaska, brown king crab *Lithodes aequispina* fishery failed to be adopted as regulation by the Alaska Board of Fisheries at their March 1997 meeting. A group of fishermen had proposed the pot limit because they believed excessive pot gear on the crabbing grounds had compromised effective management. We suggest that a manageable system of quasi property rights exists in the fishery and that the proposed pot limits would have failed to improve, and could have decreased, economic efficiency. Second, in the absence of a reliable efficiency rationale, the proposed vessel-specific pot limits were solely allocative in purpose. Furthermore, management's goal in this fishery is focused on controlling total fleet fishing power rather than the number of pots fished by individual vessels. If these assertions are true, then it may be preferable to consider the development of alternative regulatory measures that effectively address total rather than per-vessel fishing power.

INTRODUCTION

At its March 1997 meeting the Alaska Board of Fisheries considered a proposal from the United Fishermen's Marketing Association to implement a vessel pot limit in the Adak brown king crab *Lithodes aequispina* fishery (statistical area O in Figure 1). The proposed pot limits — 480 pots for vessels ≤125 ft in length and 600 pots for vessels >125 ft — were suggested to correct perceived fishery management problems associated with extensive gear usage by fishery participants. Following deliberations, the board did not adopt the pot-limit proposal, based in part, on our oral testimony, which was derived from the findings presented in this paper. Despite the Board of Fisheries' rejection of the vessel-specific pot limits on that fishery, the issue of how to properly manage the fishery has not been resolved, and vessel-specific pot quotas or area-specific pot quotas will most likely be revisited. These techniques are simultaneously being employed or examined in nearly all of Alaska's crab fisheries. Therefore, it is important to continue to publicly discuss and debate alternative management techniques aimed at reducing effort in the crab fisheries of Alaska.

This paper presents an economic evaluation of the brown king crab pot limits for Adak that focused on two major questions. First, we examined historical Adak fishery statistics to determine whether open-access problems were evident in the fishery and justified vessel-specific pot limits. Second, we examined whether the proposed pot limits were fair and equitable to different segments of the Adak brown king crab fleet, as mandated by the Magnuson–Stevens Fishery Conservation and Management Act (section 301, public law 98–623).

The Adak brown king crab fishery occurs in the federal Exclusive Economic Zone (EEZ) and is jointly managed by the state and federal government through a cooperative fishery management plan (FMP) for the Bering Sea Aleutian Islands (BSAI) king and Tanner crab fisheries (NPFMC 1989). The Adak brown king crab fishery has not been as intensively regulated as many other BSAI crab fisheries. Given this passive management, the fishery might be considered a prime candidate for the oft-cited "tragedy of the commons," whereby rational harvesters defer long-range resource interest to their short-term self interest, driving a fishery toward commercial extinction.

The consideration of pot limits in the Adak brown king crab fishery is relevant within the broader context of employing individual vessel-effort control measures to limit total fleet fishing power. Within this context, the Adak brown king crab fishery provides an

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opportunity to consider management implications of open-access versus common property fisheries. In this paper, we will attempt to demonstrate that open-access problems are not clearly evident in the Adak brown king crab fishery. In fact, quasi property rights appear to have developed in the fishery resulting in fisheries being prosecuted under a regime that more closely resembling a common property resource than an open-access resource. Christy (1982) described territorial rights as TURFs (territorial use rights in fisheries). Under current conditions of relatively low fishing pressure, common property rights appear to have effectively regulated spatial distribution of fishery effort avoiding conflict, gear loss, and excessive capitalization. Moreover, we suggest that under these conditions, individual vessel pot limits could promote the very open-access problems this regulation was proposed to avoid.

THE ADAK BROWN KING CRAB FISHERY

The Adak brown king crab fishery has been managed by the Alaska Department of Fish and Game (ADF&G) in a substantively different manner than the Bristol Bay red king crab *Paralithodes camtschaticus* and Bering Sea snow *Chionoecetes opilio* and Tanner crab *C. bairdi* fisheries. The Adak fishery has been subjected to 3-S (size, sex, season) management, like other BSAI crab fisheries, and a guideline harvest level initiated in the 1997/98 season. Before that, there was no preseason harvest expectation or inseason target harvest that would trigger a season closure announcement; instead ADF&G has managed this fishery through preseason announcement of season length. Since 1985 the fishery has been opened from November 1 to August 15, irrespective of fishery harvests. Because neither trawl surveys nor pot surveys have been conducted in the Adak region, brown king crab population estimates have not been developed.

The Adak brown king crab fishery is a small BSAI crab fishery, both in number of fishery participants and total harvest. Since 1990 the fishery has averaged 20 participating vessels and the harvest has been approximately 5.5 million pounds. As noted, season length has been a relaxed 288 d annually since 1985 (Table 1), in contrast to the very short seasons in other BSAI king and Tanner crab fisheries and recently shortened snow crab season.

The Adak brown king crab fishery occurs over an expansive geographic area (Figure 1). Currents can be

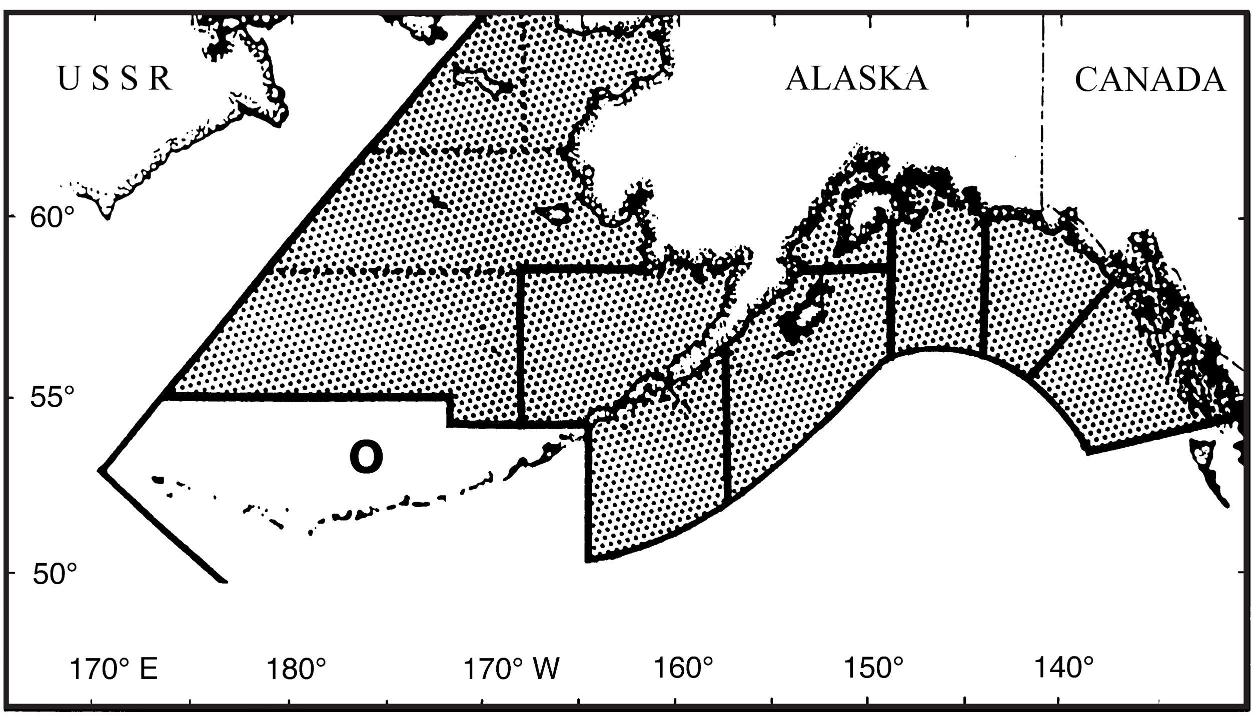

Figure 1. Adak king crab management area “O” (unshaded) and other management areas (shaded).

Table 1. The Adak brown king crab fishery harvest statistics, 1981–1996 (Source ADF&G).

Season (years)	Number of Vessels	Number of Pots	Harvest (lb)	Season Length (d)
81/82	14	2,647	1,194,046	227
82/83	99	13,111	8,006,274	166
83/84	157	17,604	8,128,029	157
84/85	38	5,270	3,180,095	240
85/86	49	7,057	11,124,759	288
86/87	62	12,958	12,798,004	288
87/88	46	10,687	8,001,177	289
88/89	74	23,627	9,080,196	288
89/90	64	14,724	10,162,400	288
90/91	13	7,380	5,250,687	288
91/92	16	7,635	6,254,409	289
92/93	18	8,236	4,916,149	288
93/94	21	11,970	4,635,683	288
94/95	34	15,604	6,378,848	288
95/96	25	14,213	4,896,911	288

extreme throughout the fishing grounds and weather conditions are frequently severe. Brown king crab molt year-round, and adults are found at varying depths to 500 fathoms. Males are stratified by depth, and by targeting the correct depth and time, an experienced fisherman can avoid, to a certain extent, crabs in molt, areas of juvenile concentrations, and excessive bycatch of other nonlegal crabs. Much of the fishing takes place on narrow ledges and on steep bottoms. Harvesters may engage in prospecting in this fishery to help determine the abundance status of crabs in various areas at differing depths. The fishery conditions require that participants have a unique set of skills and experience, which in this fishery are paramount.

The unique fishery conditions have led many participants to customize their gear and equipment in this long-line pot fishery. A typical long-line will contain a string of 20 to 30 pots, but the size and type of pots used vary widely across the fleet to better accommodate particular fishery conditions, such as a sled-like design to prevent pots from becoming lodged on the seabed. Both typical rectangular pots (e.g., 7 x 7 ft) as well as cone-shaped pots 5–6 ft in diameter are employed. In part, the type of pot used is determined by the capacity of the vessel's hydraulics. Without modification, a typical crab vessel's hydraulics do not have the capacity to retrieve a string of 20–30 typical rectangular pots.

In the absence of pot limits, many participants have chosen to make substantial investments to allow them to effectively fish a large number of pots. Fishery participants reported investments of up to $1 million in gearing up for this fishery. Pots cost $750 to $1,000 each. Fishery participants stated that by fishing many pots they are able to achieve longer soaks of their gear, often 3 d or more. Long soak times were stated to be important because of tide changes and to allow nonlegal crab escapement. A very large vessel can pull more than 400 pots/d under favorable conditions.

Fishery participants have indicated that gentlemen's agreements exist; i.e., harvesters avoid fishing near other participants and fishing in regions others have repeatedly harvested in prior seasons. This cooperation enables harvesters to return seasonally to the same fishing grounds. The ability to retain and protect fishing grounds is improved when the fishery is prosecuted by relatively few vessels, as this fishery has been since 1990.

MANAGEMENT OPTIONS FOR ALASKA CRAB FISHERIES

The Bering Sea Aleutian Island king and Tanner crab FMP incorporates management measures in 3 different categories. Pot limits are included as a category-2 measure, which means pot limits can be changed by the state following criteria set out in the FMP. Any new measures must be must be consistent with the FMP, the Magnuson–Stevens Act, and other applicable laws and may occur only after consultation with the North Pacific Fishery Management Council. Category-2 measures may be adopted under state laws, subject to the appeals process provided in the FMP.

The FMP contains a general management goal: to maximize the overall long-term benefit to the nation of BSAI stocks of king and Tanner crab by coordinated federal and state management. The FMP contains specific objectives within the scope of the management goal. These relate to stock condition, economic and social benefits, gear conflicts, habitat, safety, access to the FMP process, and research and management. The state is authorized to use pot limits to attain the biological conservation, economic, and social objectives of the FMP. From an economic perspective, perhaps the most important national standard in the Magnuson–Stevens Act that needs to be addressed is found in section 301 public law 104–297, which states that "conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources: except that no such measures shall have economic allocation as its sole purpose."

OPEN-ACCESS FISHERIES

In an open-access fishery the fishing grounds are exploited on a first-come, first-serve basis because no individual has the property rights to the fishery and, hence, no individual has the right to legally exclude another from its use. Open-access fisheries can occur in the absence of effective collectively managed fisheries designated as common property. Although open-access fisheries are now scarce, in the pure sense, many are categorized as regulated open-access fisheries. The expected outcome of an open-access fishery is the "tragedy of the commons."

In fisheries, an unregulated open-access fishery will yield an equilibrium harvest level where all rents are eventually dissipated. One of the first to recognize this problem was Gordon (1954) who concluded a theoretical discussion of the open-access problem in fisheries in this way:

> This is why fishermen are not wealthy, despite the fact that the fishery resources of the sea are the richest and most indestructible available to man. By and large, the only fisherman who becomes rich is one who makes a lucky catch or one who participates in a fishery that is put under a form of social control that turns the open resource into property rights.

Failures of open-access fishery systems have been well documented. The availability of the fishery resource on a first-come, first-serve basis can lead to unfettered competition between fishery participants and a build-up of fleet fishing power over time. This overcapitalization of the fishing fleet may occur through increases in the number of fishery participants or increases in gear and equipment employed by participants in the fishery. In the absence of adequate controls, the increased fishing pressure exerted by the fleet may lead to excessive harvests.

Fisheries with various degrees of regulations are often called regulated open-access fisheries. Regulation of open-access fisheries often involves limiting total fleet harvest through total allowable catch (TAC), guideline harvest level (GHL), or trip limit and may also include minimum size limits, mandatory release of females (sex restrictions), fishing seasons, days-at-sea limits, gear limits, registration areas, closed waters, and other fishing area restrictions. The outcome of these traditional regulatory mechanisms is usually a race for fish (i.e., each harvester makes investments in unregulated inputs that will allow them to become more effective at catching the fish before a competitor does). Open-access fisheries suffer a myriad of problems associated with the race-for-fish phenomenon. These problems include rent dissipation from overcapitalization and decreased economic efficiency. However, this is not always the case.

COMMON PROPERTY RESOURCES

Common property resources are not everybody's property. The concept of common ownership implies that those who are not members of a group of coequal rights holders can be excluded. The concept "property" has no meaning without this feature of exclusion of all who are neither owners themselves nor have some arrangement with owners to use the resource in question (Wantrup and Bishop 1975).

According to Acheson (1987), "Economic gains from the strategy of maintaining a strong defense of traditional boundaries are shown in higher mean numbers of lobsters per trap, more large and hence higher-priced lobsters, and higher gross incomes." Stevens (1991) states, "In common property systems that have survived, people have learned to limit use." Stevenson also defines common property:

> Common property is a form of resource ownership with the following characteristics:
>
> 1. The resource unit has bounds that are well defined by physical, biological, and social parameters.
> 2. There is a well-delineated group of users who are distinct from persons excluded from resource use.
> 3. Multiple included users participate in resource extraction.
> 4. Explicit or implicit well-understood rules exist among users regarding their rights and their duties to one another about resource extraction.
> 5. Users share joint, non-exclusive entitlement to the in situ or fugitive resource prior to its capture or use.
> 6. Users compete for the resource, and thereby impose negative externalities on one another.
> 7. A well-delineated group of rights holders exists, which may or may not coincide with the group of users.

The Adak brown king crab fishery has some of these characteristics and could be regulated to enhance or detract from the characteristics that promote common property behaviors. The resource is physically and biologically well-defined. There is (at present) a well-delineated group of users (management actions could promote this through limited entry or exclusive area registration). Although there are multiple users, they are few and therefore face moderate transaction costs to coordinate resource use Despite informal arrangements regarding accustomed fishing areas and avoidance of overlapping gear, ownership is by capture, and there is considerable potential for users to create negative externalities for one another. The fishery does not satisfy Stevenson's 7th condition but could under license limitation, superexclusive area registration, or similar measures to restrict entry. Currently, demand for access to the resource is similar to the early demand for grazing rights described in Anderson and Hill (1975); i.e., although there is a potential for uncooperative competition for the resource, there are few enough users to allow informal arrangements regarding "customary ranges" that minimize conflict. Our concern is that pot limits could serve as an inducement to entry, increasing the number of participants and making it impossible, through informal mechanisms, to continue to avoid the undesirable race-for-fish effects.

A variety of management measures have been used to address open-access problems. The proposed pot limit in the Adak Brown king crab fishery represents a form of input control, a commonly employed tool to limit fleet fishing power. Management options used to control the fleet harvest in the Adak brown king crab fishery include size, season, and sex restrictions; GHLs were initiated for the 1997/98 season. Alternative methods, which control the open-access nature of the fisheries, have been applied in other fisheries, for example, license limitations and individual transferable quotas.

OPEN-ACCESS PROBLEMS NOT CLEARLY EVIDENT IN ADAK

The Adak brown king crab fishery is an example of a regulated open-access fishery with potential problems. Fishery data were examined to evaluate whether characteristic prominent open-access problems — overexploitation of the stock with accompanying reductions in stock abundance, overcapitalization of the harvest sector, and rent dissipation — are evident in the Adak Brown king crab fishery. A fourth component of our discussion focuses on the structure of quasi property rights.

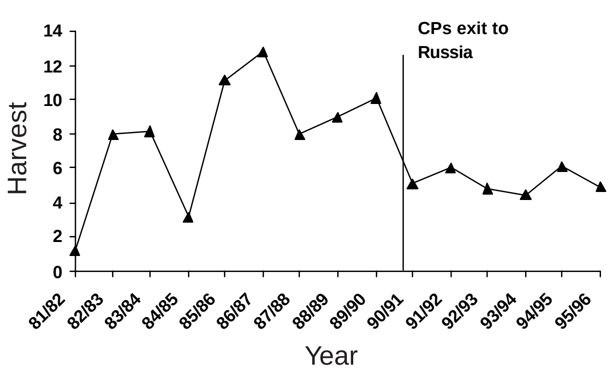

Figure 2. Total Adak harvest of the brown king crab fishery from 1981/82 to 1995/96 (in millions of pounds).

Stock Abundance

A basic problem associated with open-access fisheries is overexploitation of stock and resulting reduction in stock abundance. Because trawl survey data are unavailable for the Adak brown king crab fishery, trends in stock abundance are estimated from harvest, catch per unit effort (CPUE; as number of crabs caught per pot lift), and crab weight statistics. The uniform season lengths and lack of a GHL (until the 1997/98 season), partially justifies the use of harvest as an index of stock abundance. There are no clear indications of a declining stock abundance in the Adak brown king crab harvests. Total fishery harvest has remained fairly constant since fleet size dramatically declined (from 64 vessels to 13 vessels) between the 1989/90 and 1990/91 seasons when catcher/processors (CPs) exited the fishery to fish in the more productive Russian crab fisheries (Figure 2). Between 1989/90 and 1990/91 and in the absence of CPs, fishery harvest dropped by nearly half from 10.1 million to 5.2 million pounds.

In contrast to total fishery harvest, average per vessel harvest rose as fleet size declined in 1990/91 (Figure 3) and remained at near record levels in 1991/92. Average harvest has declined in subsequent seasons; however, most of this can be attributed to a rise in fleet size and a change in fleet composition. Numbers of small vessels (≤125) grew in proportion to large vessels (>125 feet). Average harvest during the 1995/96 year was still higher than 8 of the 14 previous years.

Further examination of Figure 3 provides an additional example of why simply inspecting average vessel performance may be misleading. Large-vessel average harvest severely decreased in 1994/95, contributing to a decline in fleet average harvest. However, rather than reflecting a general performance trend across large vessels, much of this decline was due to the entrance of a single large vessel into the fishery that chose to fish considerably smaller cone-shaped pots and recorded a significantly lower CPUE. This was not accounted for in the fish ticket data.

Similar findings are evident in the fishery CPUE data (see Figure 4). Across the fleet, CPUE drifted downward in recent years. But a clear trend is not evident when CPUEs are examined by vessel size class. The proportional increases in fishery participation by small vessels, which exhibit lower CPUEs, distorts the fleet average CPUE downward. If the one large vessel fishing smaller cone-shaped pots during the 1994/95 season were removed from the CPUE data, then the large-vessel CPUE would have remained fairly stable from 1988/89 to 1994/1995, with the exception of the phenomenal 1993/1994 year. The overall average CPUE in 1995/96 rose slightly from the previous year. In any case, it is difficult to compare CPUEs across years because of changes in fleet and gear composition. As was mentioned, the 1994/95 CPUE was lowered by a large vessel fishing smaller pots. The average 1994/95 CPUE for vessels that had participated in the fishery in each of the prior six seasons (for which we had fish ticket data) was 8.0, substantially higher than the fleet average of 4.7. The possible effects of experience to vessel performance in this fishery will be discussed later.

Finally, we examined the average weights of harvested crabs across years for indications of declining stock abundance. A declining average weight would be consistent with greater concentrations of young/small crab in the fishery's catch. Both fishery managers and fishery participants have reported a decline in the catch of older/larger adult male brown crabs. However, the average weight of harvested crabs has remained fairly constant since the 1985/86 season, when the carapace width size limit was lowered from 6.5 to 6 in.

In summary, examination of total and average harvest, average CPUE across vessel size classes, and the average weight of harvested crabs are inconsistent with stock depletion expected in a problematic open-access fishery. However, the period since the CPs exited the fishery is very short.

Fleet Capitalization

A second characteristic of open-access fisheries is increased fleet capitalization over time. Recent fishery data were examined to evaluate whether there has been a buildup in fleet capitalization (see Figure 5).

The number of participating vessels grew modestly following the precipitous 1990/91 decline, but this trend ended in 1995/96 when only 25 vessels participated in the fishery.

The number of registered pots in the fishery has grown slightly over recent years. However, this increase is largely attributable to increases in fleet size rather than changes in the number of pots employed by individual vessels. The average number of registered pots per vessel has remained stable since the 1990/91 season (when catcher/processors exited the fishery), except for a slight increase during the most recent season (see Figure 6).

Other vessel capacity measures, such as vessel length, fuel capacity, and gross tonnage, found in the ADF&G registration files, were also examined for indications of growth in fleet capitalization. However, none of these vessel-capacity measures exhibited growth in recent years.

Rent Dissipation

Open-access fisheries are also reported to lead to dissipation of fishery rents. Cost data were not available, so rents could not be directly estimated. However, examination of average exvessel revenues revealed that gross returns from the fishery have remained relatively high in recent years. Recent declines in average vessel revenues for the fleet can be attributed, in part, to increased participation of small vessels in the fishery,

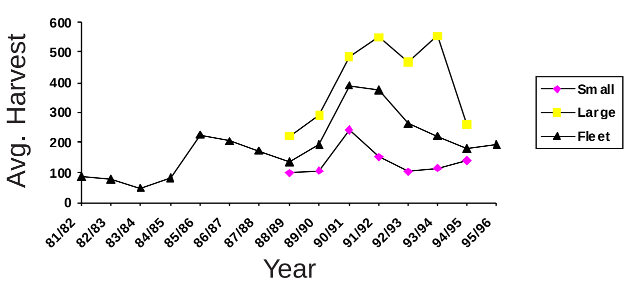

Figure 3 Average harvest for large (>125 ft) and small (≤125 ft) vessels and the overall fleet in the Adak brown king crab fishery, 1981/82 to 1995/96 (in thousands of pounds) (individual vessel performance data were not yet available for the 1995/96 season).

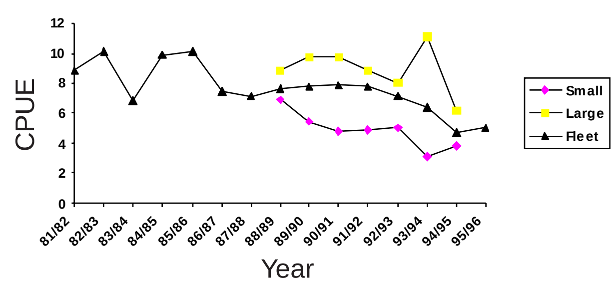

Figure 4. Average CPUE for large (>125 ft) and small vessels (≤125 ft) and the overall fleet in the Adak brown king crab fishery from 1981/82 to 1995/96.

Table 2. Vessels characterized by whether they would have been constrained by the proposed pot limit based on pots registered during the 1994/95 Adak brown king crab season.

Vessel Group	Total Nr Pots Registered	Pots Lost with Proposed Pot Limit	Pots Left with Proposed Pot Limit	Harvest (Nr Crabs)	Harvest % of Total, 1994/95	CPUE
10 Constrained Vessels	7,850	2,570	5,280	742,737	50%	5.4
24 Vessels Unconstrained	6,555	0	6,555	733,821	50%	4.1
Fleet	14,405	2,570	11,835	1,476,558	100%	4.7
4 Constrained Large Vessels	3,500	1,100	2,400	471,981	32%	7.1
6 Constrained Small Vessels	4,350	1,470	2,880	270,756	18%	3.8

rather than declines in average returns to large and small vessels (Figure 7).

One possible contributing factor to the 1994/95 fleet expansion (to 34 vessels) is that harvesters viewed quasi rents as being available in the industry. Furthermore, the 1995/96 decline in fleet size may indicate that for many harvesters these perceived quasi rents were no longer available after exvessel prices sharply declined (from \$3.33/lb for the 1994/95 season to \$2.10/lb for the 1995/96 season) and costs increased under the new observer requirements. Of course, discussion of fishery rents is highly speculative given the limited available data and the brief temporal span of the data.

Property Rights

As noted, the underlying cause of problems in open-access fisheries has been attributed to the incomplete specification of property rights (Gordon 1954). However, Adak brown king crab fishery participants reported that a quasi-property rights system is present in the fishery; industry participants indicated this in both phone interviews and in testimony before the Alaska Board of Fisheries. Harvesters indicated that they recognize the claims of other harvesters to exclusive access to the fishing regions they have historically fished. These types of agreements TURFS may avoid problems associated with vessels fishing in close proximity to one another (Christy 1982). Under this type of arrangement, the fleet may avoid typical open-access problems. Harvesters would manage their region to assure healthy annual returns. Certain participants have adopted long-term investment strategies based on these TURFs. The existence of a quasi-property rights system is consistent with the observed absence of growth in vessel capitalization.

Because quasi property rights lack a legal foundation, they may dissolve over time. Currently, with relatively few participants and a large geographic region,

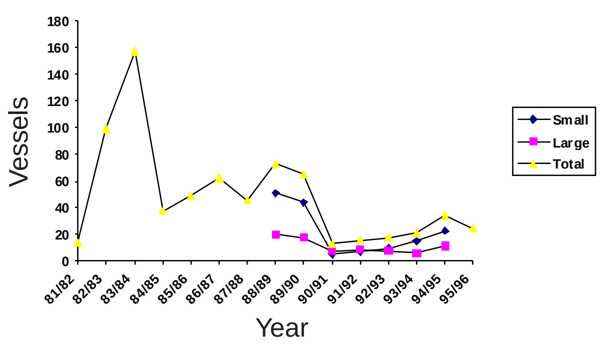

Figure 5. The number of large (>125ft), small (≤125 ft) vessels and total fleet vessels in the Adak brown king crab fishery from 1981/82 to 1995/96.

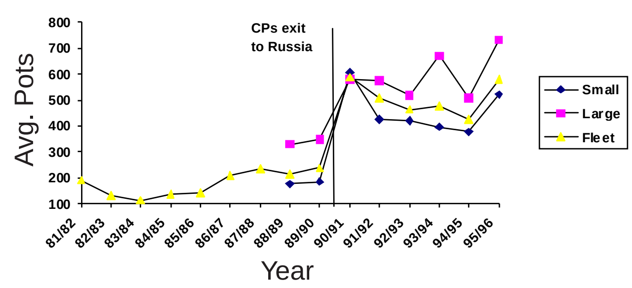

Figure 6. The average number of registered pots for large (>126 ft), small (≤125 ft) and total fleet vessels in theAdak brown king crab fishery, 1981/82 to 1995/96.

Table 3. Average vessel performance by the number of years of participation in the Adak brown king crab fishery (1988/89–1994/95).

Vessel Performance and Size	Number of Years Fished: 1988/89–1994/95						
	1	2	3	4	5	6	7
Avg Harvest Nr	8,450	22,290	52,852	68,372	55,953	90,521	182,758
Avg Nr Pots	213	236	382	391	278	438	732
Avg Pots Pulled	2,547	4,590	8,252	8,955	7,254	10,693	19,299
Avg CPUE	3.3	4.9	6.4	7.6	7.7	8.5	9.5
Avg Vessels Length (ft)	114	140	116	113	131	118	130

it may be in each harvester's self interest to establish and recognize rights of vessels to fish particular regions. However, if there was a sudden influx of vessels, particularly vessels new to the fishery, the TURF system may break down as competition intensifies on the fishing grounds. A vessel pot limit, to the extent that it encourages new entrants or limits the ability of existing vessels to define adequate fishing grounds, may contribute to a breakdown of TURFs and provoke an economic and ecologically wasteful race for fish.

De Facto Allocation

The effects of pot limits (480 pots on small vessels and 600 pots on large vessels) on the de facto allocation of fishery harvest was the second focus of the economic study. Using 1994/95 fish ticket information (the latest fish ticket information available at the time of the study), we examined the effects of a pot limit on various vessel groups in the Adak brown king crab fishery (see Table 2).

During the 1994/95 season, 10 vessels would have been constrained if the proposed pot limit had been in place: 4 would have been restricted to 600 pots, 6 would have been limited to 480 pots, and together these vessels would have lost 2,570 pots (33% of their pots).

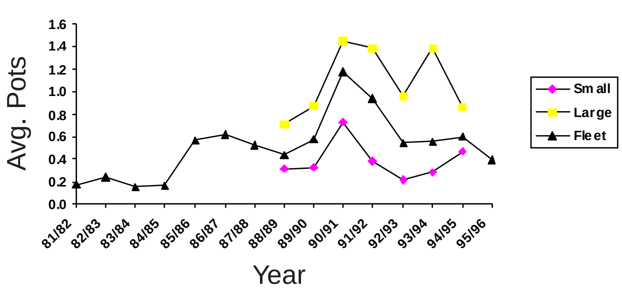

Figure 7. Average exvessel revenues for the Adak brown king crab fishery for large (≥125 ft) and small (≤125 ft) vessels and for the overall fleet, 1981/82 to 1995/96 (in million of dollars).

The fleet as a whole would have experienced an 18% reduction in pots. The 10 constrained vessels caught 50% of fleet harvest and had a CPUE of 5.4, compared to an average CPUE of 4.1 for the remainder of the fleet.

The large vessels caught 32% of the total fleet harvest. Vessels within this size class would have lost 1,100 pots or 31% of their total pots. The large vessels that would have been constrained by the pot limit had a CPUE of 7.1, substantially higher than the fleet average of 4.7. The small vessels constrained by the pot limit would have had their registered pots reduced by 34%. This group caught 18% of the fleet harvest and had a CPUE of 3.8, nearly equal to the average CPUE for vessels unconstrained by the pot limit.

The fishery data supports the contention of fishery participants that additional gear allows them to fish more effectively; that is, a large quantity of gear is needed to obtain necessary soak time, to locate crab, and to mark fishing grounds, all of which are helpful given the specific characteristics of this fishery. Furthermore, as noted, some fishery participants indicated that they are able to return seasonally to the same fishing grounds where their knowledge of local conditions allows them to minimize the harvest of undersized crabs.

Fishermen who have been in the fishery for a long time are the ones who are fishing the larger number of pots and obtain a higher average harvest and CPUE (Table 3). These are the fishermen who would be most restricted by a pot limit.

The CPUE rises without exception as experience in the fishery increases. In particular, performance of fishermen who have fished in all of the past 7 years is remarkably higher than fishermen with less experience. Average harvest for these fishermen exceed 180 thousand crabs (760 thousand lb). The number of pots they carry exceeds those carried by less experienced fishermen as do their total pot pulls. These fishermen are the most likely to use excess pots to defend their fishing grounds and therefore enforce quasi property rights.

Table 4. Estimated Adak brown king crab fishery vessel harvest equation for the 1994/95 season.

	Estimated Harvest Equation			
Variable	Estimated Parameter	*t*-ratio	One-sided *P*-value	Mean Elasticity
Constant	-2.85E+05	-2.6	0.0088	-1.33
Potlifts	15.52	3.8	0.0006	0.78
Pot-Numbers.	114.56	1.0	0.1649	0.24
Participation Days	359.46	1.2	0.1224	0.29
Experience	1.32E+05	1.6	0.0630	0.16
Vessel Length	1599.5	1.9	0.0364	0.87

R^2 = 0.807 Adjusted R^2 = 0.756 F = 5.018 df = 19

They argue that they best know their grounds and take care of them because they expect to return annually. The proposed pot limits would have hurt these most experienced fishermen and reduced their fishing effectiveness, leaving the more inexperienced fishermen with a much greater percentage of the overall pots fished.

ECONOMETRIC ANALYSIS

Model Estimation

An econometric model of vessel performance for the 1994/95 season was constructed to further examine potential affects of an Adak pot limit. We estimated vessel harvest and vessel potlifts using equations that represent harvest and potlifts as functions of the number of pots fished and other factors that affect fishing performance. Data were obtained from ADF&G fish ticket, pot registration, and vessel registration databases.

We would have preferred to estimated the models using pooled time-series data (i.e., data from each vessel for a series of seasons), but data limitations precluded such. Conditions in the Adak brown king crab fisheries have changed dramatically between seasons. Furthermore, time-series observations on some critical explanatory variables of vessel performance were not available. For example, data are not available on crab abundance nor for various oceanic conditions (e.g., weather, currents, water temperatures).

Within the modeling context, vessel harvests are represented as a function of vessel potlifts, pot numbers, length of participation time in the fishery, experience, and vessel characteristics (equation 1):

(1) Vessel Harvest = f1(Vessel Potlifts, Pot Numbers, Participation Days, Experience, Vessel Characteristics)

Vessel potlifts were represented as dependent on vessel harvest, pot numbers, length of participation in the fishery, and vessel characteristics (equation 2):

(2) Vessel Potlifts = f 2(Vessel Harvest, Pot Numbers, Participation Days, Vessel Characteristics)

All equations were estimated using ordinary least squares (OLS) with the SHAZAM econometric package; 2- and 3-stage least squares methods, often used for simultaneous systems, were not used because of low correlations between the system's exogenous vari-

Table 5. Estimated Adak brown king crab fishery vessel potlift equation for the 1994/95 season.

	Estimated Potlifts Equation			
Variable	Estimated Parameter	*t*-ratio	One-sided *p*-value	Mean Elasticity
Constant	-11620	-1.1	0.1422	-1.09
Harvest	2.24E-02	3.9	0.0004	0.45
ln(Pot-Numbers)	1781.9	1.1	0.1422	0.98
Participation Days	15.336	1.3	0.1042	0.25
Gross Tonnage	21.782	1.4	0.0884	0.41

R^2 = 0.716 Adjusted R^2 = 0.659 F = 3.151 df = 20

Table 6. Adak brown king crab fishery projections of average number of pots simulated for the 1994/95 fishery for the baseline and pot-limit scenarios by vessel size class (small, large, and fleet) and for the 4 vessels with the most pots registered.

	Vessel Pot Numbers				
Scenario	Vessel Size	Average	Change	% Change	Total Pots
Baseline	Small	419			7,545
	Large	516			3,613
	Fleet	446			11,158
	4-Highest	962			3,850
Pot Limit	Small	349	-69	-16	6,295
	Large	387	-128	-24	2,713
	Fleet	360	-86	-19	9,008
	4-Highest	540	-422	-43	2,160

ables and the equations' right-side endogenous variables in the first stage. When the correlations between the instrumental variables and the right-side endogenous variables are low, OLS may provide estimates with lower mean-squared errors than simultaneous equation methods (Johnson 1972 et al. 1990).

Thirty-four vessels participated in the 1994/95 season. However, only 25 of 34 participating vessels were included in model estimates because observations on vessel length and permit-holder experience were not available for all vessels and because vessels reporting harvests <1,000 lb or >500 potlifts were omitted.

The estimated harvest equation conforms with economic theory regarding expected signs and parameter magnitudes (Table 4). The R2 of 0.807 means the harvest equation explains approximately 81% of the variation in vessel harvest. Two of the explanatory variables, potlifts (P = 0.001) and vessel length (P = 0.036), have a one-sided P-value <0.05. The t-values on the remaining explanatory variables exceed 1, which was considered acceptable using the mean-square-error criterion (removing these variables could lead to biased parameter estimates). It is often more important to have unbiased estimates of statistically significant parameters than it is to maximize the efficiency of the overall equation. The absence of high t-values on pot numbers, participation days, and experience may reflect the lack of complete information on these variables and the use of proxies. More likely, the lower t-values are a consequence of a relatively low number of observations used for the estimations. Previous studies with a similar equation structure and a large number of observations found these variables to have very significant values (Greenberg and Herrmann 1994).

Vessel length was included in the equation as a measure of vessel capacity. The elasticity of harvest, with respect to pot numbers, deserves particular attention because the proposed policy in the Adak fishery would affect vessel pot numbers. The presented elasticity states that a 1% decrease in the mean number of registered pots would lead a 0.24% decline in vessel harvest, all else equal.

Table 7. Adak brown king crab fishery projected average harvest as simulated for the 1994/95 fishery for the baseline and pot limit scenarios by vessel size class (small, large, fleet) and for the 4 vessels with the most pots registered.

	Vessel Harvest				
Scenario	Vessel Size	Average	Change	% Change	Total Harvest
Baseline	Small	155,234	0	0	2,794,211
	Large	360,518	0	0	2,523,628
	Fleet	212,714	0	0	5,317,839
	4-Highest	525,232	0	0	2,100,927
Pot Limit	Small	138,356	-16,878	-10.9	2,490,399
	Large	331,549	-28,969	-8.0	2,320,841
	Fleet	192,450	-20,264	-9.5	4,811,240
	4-Highest	427,398	-97,833	-18.6	1,709,593

The estimated potlift equation (Table 5) had an R2 of 0.716. Only one of the variables, harvest, has a significant one-sided *P*-value; variable significance may be affected by data limitations. Gross tonnage was included in the equation to capture potlift variation associated with variation in vessel capacity. The natural logarithm of pot numbers was chosen for inclusion in the potlift equation to reflect the expectation that vessel potlifts will be less responsive to changes in pot numbers at higher levels of pot usage.

Model Simulation

The econometric models presented in the previous section provide measures of the model's ability to capture variation in 1994/95 vessel performance. In this section, the estimated harvest and potlift equations are combined into a system of equations that are simultaneously solved through model simulation. The simulations are employed to evaluate effects of the proposed pot limits to fishery participants.

Of particular interest in evaluating the simulation results, is the average impact of pot limits on large vessels and small vessels, as well as the entire fleet, rather than on individual vessels. Simulation results are also presented for the 4 vessels included in the simulations that reported the highest number of registered pots in 1994/95. The intent of this analysis is not to forecast or predict future vessel performance under a given fishery pot limit; rather, the simulations indicate what the effects of a pot limit would have had, given the 1994/95 fishery performance and fleet characteristics. The pot limit simulations are estimated based on the assumption that the proposed limit was adopted for the Adak brown king crab fishery (Table 6).

Imposition of the pot limit would effect a fleetwide reduction of 2,150 pots in the fishery (19%). Vessels would, on average, fish 86 fewer pots under the pot limit. The average pot reduction for large vessels would be greater than that of small vessels (large vessels incur a 25% reduction, small vessels incur a 17% reduction). This occurs even though, under the stratified pot limit, large vessels have a 600-pot cap and small vessels a 480-pot cap. The 4 fishers with the greatest number of pots would have suffered a 43% reduction in the average number of pots they registered. The pot limit narrows the difference in the number of pots fished per vessel across the 2 vessel size classes. Prior to the pot limit, large vessels used on average 97 more pots than small vessels. With the pot limit in place, the average difference is reduced to 38 pots.

The reduction in fleet harvest (Table 7) is modest compared to the reduction in pot numbers. For example, average harvest for the fleet and each of the vessel size classes is reduced by nearly 11% for a 19% reduction in pots. This occurs because the vessels will reduce their least effective pots first when pot limits are imposed. Large vessels in comparison to small vessels suffer a significantly larger reduction in average harvest (28,970 vs 16,878 lb).

Harvest reductions would translate into losses in exvessel revenue. Using the 1994/95 exvessel price of \$3.33/lb, the simulated reduction in average harvest represents average exvessel revenue declines of \$56,205 for small vessels, \$96,469 for large vessels, and \$67,479 for the fleet. The average exvessel revenue reduction to the 4 largest pot holders is \$325,785. Note however, that these simulations are conducted on estimations based on relatively few observations; therefore, the figures should be viewed only as a first attempt to approximate the actual effects of pot limits.

We assumed in conducting the simulations that past fishery practices would continue under a pot limit. However, in practice, harvesters will adjust their fishing practices to accommodate limits on gear. Furthermore, the pot limits may lead to vessel entries or exits. That is, the pot limit-induced reductions in exvessel revenues may contribute to some vessels exiting the fishery. This may particularly hold for vessels whose owners have invested heavily in gearing up for this fishery. According to simulation results, these vessels would suffer significantly greater exvessel revenue reductions than other fleet vessels. A vessel pot limit may also serve to encourage new participants to enter the fishery. There is a large pool of potential entrants, including many of the 200–300 vessels that have participated in recent years in other Bering Sea/Aleutian Islands king, snow, and Tanner crab fisheries. There are several incentives that pot limits could provide to these potential new fishery entrants. First, a pot limit would weaken the ability of current participants to define fishing territories, opening potentially productive fishing grounds to new participants. Moreover, if we view the number of pots as being an important contributor to vessel fishing power, then pot limits improve the competitiveness of new vessels by reducing the relative fishing power of current vessels. Finally, given that pots cost \$700–\$1000, the cost of gearing up for the fishery are severely reduced at low pot limits.

DISCUSSION

Proposed pot limits for the Adak brown king crab fishery were not adopted by the Alaska Board of Fisheries in their March 1997 meeting, but the issue has not become acquiescent. Many believe that would make the fishery more manageable by reducing excessive gear on the crabbing grounds. Some also suggest that the large number of pots carried by larger vessels keeps smaller operations out of productive fishing grounds.

The Adak brown king crab fishery is a fishery that has the potential to develop problems associated with regulated open-access fisheries, such as over-exploitation of fish stocks and accompanying reductions in stock abundance, overcapitalization of the harvesting sector, and rent dissipation. We examined the Adak brown king crab fishery to determine whether open-access problems were evident The imposition of pot limits, without a simultaneous limitation on total effort (e.g., license limitations or a fleetwide cap on pots) could open the fishery to wasteful capitalization and a breakdown of TURFs, resulting in an economically and ecologically wasteful race for fish.

Fishery harvests, fleet composition, CPUE, and the size of harvested crab clearly indicated declining stock abundance. Recent fishery data also indicated a significant buildup in fleet capitalization. Examination of fishery average exvessel revenues revealed that gross returns from the fishery have remained relatively high in recent years, excluding the precipitous 1995/96 season decrease related to exvessel price. This economic vitality could change because open-access fisheries can lead to dissipation of fishery rents (Gordon 1954).

The underlying cause of problems in open-access fisheries has been attributed to incompletely specified property rights. Although participants in the Alaska brown king crab fishery lack legally enforceable property rights, harvesters reportedly recognized each others claims of exclusive access rights to their historical fishing areas. These types of agreements avoid problems associated with vessels fishing close to one another. Under this type of arrangement, the fleet may avoid typical open-access problems. Harvesters have an incentive to manage their region to assure healthy annual returns, to the degree they feel secure in the exclusivity of their access to crabs in their customary and traditional fishing area. Some harvesters appear to have adopted long-term investment strategies based on the quasi property rights arrangement, which is possible because of the absence of over-capitalization. Under this self-regulated system, the Adak brown king crab fishery exhibits characteristics of a successfully operating common property fishery rather than those of a regulated open-access fishery.

Because quasi property rights are not based in law, this successful common property arrangement may collapse over time. With relatively few participants and a large geographic region, it appears to have been in the harvesters' self interest to establish and recognize rights of one another to fish particular regions. However, a sudden influx of vessels, particularly vessels new to the fishery, might break down this quasi-property rights system as competition intensifies. A pot limit, to the extent that it encourages new entrants or limits the ability of existing vessels to define adequate fishing grounds, may contribute to a break down of quasi property rights. Thus, a vessel-specific pot limit may actually lead the fishery to problems associated with open-access fisheries, which is exactly what pot limits were supposed to supress. As an alternative, managers could explore ways of strengthening current informal property rights (e.g., moratorium on entry, territorial use permits, etc.) as a means of protecting the fishery from related open-access problems.

The econometric models of 1994/95 vessel harvest and potlifts helped evaluate the effects of the proposed pot limits on the fleet, specifically changes in fleet performance. The pot limit would greatly narrow the average difference in the number of pots fished by small and large vessels. The 4 vessels with the greatest number of registered pots suffered significantly greater average harvest reductions than the whole fleet or either of the vessel size classes. Using the 1994/94 exvessel price of $3.33/lb, the harvest reductions translated into average exvessel revenue declines of $56,205 for small vessels, $96,469 for large vessels, and $67,479 for the fleet. The average exvessel revenue decline to the 4 vessels with highest number of registered pots was $325,785.

Under the national standard (section 301, public law 104–297) mandated in the Magnuson–Stevens Act, "conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery policy resources: except that no such measures shall have economic allocation as its sole purpose." Viewing the proposed pot limits under this stipulation, the proposed pot limits fail on both accounts. First, there is no substantial evidence that vessel-specific pot limits will improve efficiency and may, in fact, decrease economic efficiency. Second, in the absence of efficiency gains, the pot limits are solely allocative in purpose.

Whether pot limits will be effective in reducing total fleet pots is a matter of conjecture. However, consideration of this point does lead to the important issue of whether vessel pot limits are the appropriate tool in this fishery. The management goal appears to focus on controlling the total number of pots in the fishery rather than the number of pots fished by individual vessels. If that is true, then it may be preferable to consider an alternative pot-limit system or other regulatory measures that better address limiting the total number of pots on the fishing grounds.

ALTERNATIVE MANAGEMENT STRUCTURES

Many of the Adak brown king crab fishers said that the fishery was running smoothly with the current 25 vessels fishing a combined 14,000–15,000 pots and that gear restrictions were not needed. They feared the return of fishery conditions similar to the 1988/89 season when 74 vessels fished nearly 24,000 pots. Avoiding this level of fishing pressure may well be better addressed by managing the total number of pots on the fishing grounds rather than the number per vessel. One alternative is an individual transferable pot quotas (ITPQs) program, as discussed by Greenberg et. al (1994) for the Bristol Bay red king crab fishery and the Bering Sea snow crab fishery. The Florida spiny lobster fishery is an example of a fishery currently managed under an ITPQ system (Orbach and Johnson, 1991).

An ITPQ system is similar to an individual transferable quota system, except pot quotas (PQs) would represent property rights to gear rather than to a percentage of fishery harvest. Each qualified harvester would receive pot quotas (PQs), representing the initial number of pots they are entitled to fish. The initial system of allocating pot quotas would have to be determined, though they could be assigned based on historical fishing practices similar to how harvest quota shares have commonly been allocated. The PQs would be transferable such that owners of PQs could sell PQs, and potential entrants or current participants could purchase PQs they do not own. The total number of PQs initially allocated would be based on the desired pot cap.

The ITPQ system would represent a fundamental change in the institutional setting under which the crab fisheries are prosecuted, and past behavior may not be a good indicator of future behavior under this changed setting. Some of the expected benefits include efficiency gains that would be achieved through owners being able to make investment decisions with full knowledge of how many pots will be on the fishing grounds. Fishing effectiveness could be enhanced by allowing vessel operators to determine the optimal number of pots they fish. More efficient operators would buy pots from less efficient operators. Participants in the fishery may prefer the ability to make their own decisions and to use their skill to determine their financial success. Finally, harvesters who wished to exit the fishery or downsize would receive compensation from those wanting to enter the fishery or expand their harvest. An additional benefit in the case of the Adak brown king crab fishery is that an ITPQ could protect those participants who have made substantial investments in vessels, gear, and equipment. Adjustments to existing PQs would occur through voluntary market exchange, rather than by management edict.

Another alternative would be to formally lease or permanently transfer spatially defined rights. Spatial rights have been used to control grazing activities on public range lands, petroleum, and mineral production on state and federal lands and on the outer continental shelf. Spatial rights have also been defined for shellfish fisheries. For example, oyster beds have been leased in some states since the 18th century (Agnello and Donelly 1975) and abalone fisheries and other near shore fisheries in Japan have been managed on communal spatial rights (Ruddle 1989, 1994). Cod fisheries in northwest Norway have also been managed on exclusive territorial rights to litoral communities (Jentoff and Mikalsen 1994), and similar rights have been documented in Brazil (Cordell and McKean 1992). Territorial use rights could be transferable or nontransferable, subject to performance clauses or harvest limitations. Schlanger (1994) identifies necessary and sufficient conditions for the development of TURFs.

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