POTENTIAL CONFLICTS BETWEEN SEA OTTERS AND THE HUMAN UTILIZATION OF SHELLFISH IN SOUTHEASTERN ALASKA

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Sea otters (*Enhydra lutris*) were apparently abundant in Southeastern Alaska prior to exploitation during the 18th and 19th centuries. Kenyon (1969) reported that they were essentially eliminated from the area before 1900. Sea otters have since become reestablished as the result of translocations from Amchitka Island and Prince William Sound in the late 1960's (Burris and McKnight 1973), and total numbers now exceed 3,600 (Pitcher 1987). Sea otter populations in southeastern Alaska, although largely limited to the outside coast, have been rapidly expanding both in numbers and range. Annual rates of increase have averaged 18% over the past 12 years (Pitcher 1987). It is expected that these populations will continue to grow and expand their ranges for a number of years, although it is not know to what degree they will colonize inland waters.

Sea otters prey primarily on benthic invertebrates (including molluscs, echinoderms and crustaceans), although fish are also a significant food in some of the Aleutian Islands (Estes and VanBlaricom 1985). Otters are effective predators that limit the age structure, size and abundance of many of their prey. Compared with sea otters, most prey species are relatively immobile making them particularly vulnerable to predation (Estes and VanBlaricom 1985). In addition, the metabolic rate of sea otters is 2.5-3.0 times that of terrestrial mammals of similar size (Costa and Kooyman 1984), and they consume food equivalent to about 23% of their body weight daily (Costa 1982). It appears that some prey species are able to coexist with sea otters only by persisting as small individuals or by utilizing areas that hinder access by otters such as cracks and crevices (Lowry and Pearse 1973, Hines and Pearse 1981) or deep water.

After sea otters were reduced by human exploitation to a few small, remnant populations in the latter part of the 19th century, a number of species of shellfish, which formerly had been limited by otters, became abundant (Estes 1981). These included abalones, sea urchins, and several species of clams and crabs. In the absence of sea otters, commercial, subsistence, and sport fisheries developed on these populations that contained many old and large individuals. Now with the recovery of sea otter populations, human utilization of some shellfish is being reduced or precluded by otters.

In California, availability for human harvest of abalones (*Haliotis spp.*), sea urchins (*Strongylocentrotus spp.*), and Pismo clams (*Tivela stultorum*) appears to have been sharply reduced by sea otter predation (Lowry and Pearse 1973, Hines and Pearse 1982, Estes and VanBlaricom 1985, Wendell et al. 1986). In Alaska, the impacts of otter predation on human utilization of shellfish populations have not been well documented and are largely anecdotal in nature. Conflicts

appear to be increasing as sea otter populations grow and expand into more populated areas. Reports from fishermen suggest that sea otters have substantially reduced abundance of legal-size abalones along stretches of the outside coast of southeastern Alaska. Some clam beds appear to have been depleted of large individuals by otters in the northern Kodiak archipelago (A. DeGange, pers. comm.). Strong circumstantial evidence indicated that sea otter predation on dungeness crabs (*Cancer magister*) precluded human use in the Orca Inlet area of Prince William Sound (Garshelis and Garshelis 1984, Garshelis et al. 1986). Residents of Elfin Cove, in southeastern Alaska, indicated to me that reduced availability of dungeness crabs in nearby Port Althorp coincided with the arrival of sea otters in large numbers in that area. Johnson (1982) reported reduced availability of clams and dungeness crabs in portions of northeastern Prince William Sound after the arrival of sea otters.

Based on these reports, it is anticipated that additional conflicts between human utilization of shellfish and expanding sea otter populations in southeastern Alaska will develop. It is the purpose of this report to identify and review both the magnitude and geographic distribution of the various shellfisheries in southeastern Alaska and to evaluate the potential impacts of sea otter predation on those fisheries. Areas particularly important for the harvest of various shellfish will be identified to aid in consideration of zonal management of sea otters and shellfisheries.

Shellfish species which are currently harvested commercially in southeastern Alaska include red king crab (*Paralithodes camtschatica*), blue king crab (*P. platypus*), brown king crab (*Lithodes aequispina*), tanner crab (*Chionoecetes bairdi*), dungeness crab, shrimp (*Pandalus spp., Pandalopsis dispar*), northern abalone (*H. kamtschatkana*), weathervane scallop (*Pactinopectin caurinus*), geoduck clam (*Panope generosa*), green sea urchin (*S. drobachiensis*), and red sea urchin (*S. franciscanus*). Preliminary harvesting has been directed at octopus (*Octopus dolfleini*), squid (*Loligo opalescens*), and sea cucumber (*Parastichopus californicus*), although established fisheries have not yet developed. Most of these species are also the target of subsistence or personal use fisheries.

Red king crabs, blue king crabs, bairdi tanner crabs, dungeness crabs, sea urchins, and abalones all occur in shallow water (<20 fathoms) during all or portions of their life cycles. This is well within the feeding range of sea otters (Kenyon 1969, Newby 1975). Dungeness crabs, sea urchins, and abalones have all been reported as major prey of otters (Hines and Pearse 1982, Estes and VanBlaricom 1985, Garshelis et al. 1986). King crabs and tanner crabs have been reported as sea otter prey (Kenyon 1969; Johnson

1988; Alaska Department of Fish & Game [ADF&G], unpubl. data), although not as a major component of the diet. They would appear to be energetically profitable prey, similar to dungeness crabs (Garshelis et al. 1986), if readily available. Few feeding studies have been conducted in areas where these species occur, which perhaps explains their infrequent mention as sea otter prey. Brown king crabs and weathervane scallops are not known to be sea otter prey. They usually occur in deep water and are probably seldom available to otters. Shrimp, while abundant over much of the sea otters range, have never been reported as a commonly utilized prey. Geoduck clams (Rosenthal and Barilotti 1973), octopus (Kenyon 1969, Johnson 1988), squid (Faurot et al. 1986), and sea cucumbers (Johnson 1988) have all been recorded as sea otter prey but not as composing substantial portions of their diet.

Based on these observations, it appears that the only species of shellfish in southeastern Alaska that are exploited to a significant degree and have a high likelihood of being impacted by sea otter predation are sea urchins, abalones, dungeness crabs and possibly red and blue king crabs, tanner crabs and geoduck clams. Discussions in the rest of this report will be largely limited to these species.

METHODS

Historical commercial shellfish harvest records maintained by Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries, were reviewed to determine the magnitude and geographic distribution of harvests of the species of interest. It was felt that harvest data were a good indicator of relative abundance throughout southeastern Alaska for abalones, red king crabs, tanner crabs, and dungeness crabs because these species are apparently fully exploited. Both the geoduck clam and sea urchin fisheries are still in developmental phases, and harvest distribution reflects regulatory and marketing restraints rather than biological distribution. The major sources of background information on these fisheries were the annual ADF&G staff reports to the Board of Fisheries (Koeneman and Imamura 1986, 1987). Interviews were conducted with Timothy M. Koeneman, coordinator of the southeastern Alaska shellfish program, and Donald E. House, a fishery biologist involved with the sea urchin harvest program. Ex-vessel prices paid by processors to fishermen were obtained from Elaine Dinneford, a research analyst with the Commercial Fisheries Entry Commission.

To identify and rank areas according to their importance as shellfish producers, the total harvest of the selected species for the 10-year period 1975-1984 was calculated for each of the 15 ADF&G statistical harvest districts that compose southeastern Alaska (Figures 1-3). An index to the value of the harvest for each statistical district was calculated by multiplying the total harvest of each species for the 10-year period by the average ex-vessel price during 1983 and 1984, the last two years when red king crab seasons were open. The totals for each species were then summed to provide a total value for each statistical area for those species that potentially could be impacted by sea otters.

Reports produced by ADF&G, Division of Subsistence were reviewed to obtain information on subsistence or non-commercial harvests of shellfish in southeastern Alaska.

RESULTS AND DISCUSSION

Geoduck Clams

A fishery for this species is currently in the developmental stage. Geoduck beds occur sporadically in central and southern southeastern Alaska, primarily near the outside coast. Prior to 1985 a few geoducks were harvested for bait or test marketing; 1,632 lb were reported marketed between 1980 and 1984. Additionally, 3 state grants to private industry were used to explore for geoduck beds with commercial potential. Geoducks, like other filter feeding bivalve molluscs, concentrate the paralytic shellfish poisoning (PSP) toxin produced by planktonic dinoflagellates in their tissues. Before they can be marketed they must be processed and the viscera, where most of the toxin is confined, removed. Each delivered lot of processed geoducks must certified free of PSP by the Alaska Department of Environmental Conservation prior to marketing. In addition, before a geoduck bed can be exploited, it must be surveyed by ADF&G to estimate biomass so that a harvest quota (2% of total biomass = annual harvest quota) can be established.

In 1985 3 beds were surveyed near Noyes Island and 18,917 lb were landed. In 1986, 130,961 lb were harvested from these same beds; this amount was less than half of the annual quota. Ex-vessel price was $0.25/lb. Because of industry interest in harvesting areas nearer to transportation centers, beds along the outside coast of Gravina Island, near Ketchikan, were surveyed in 1987. An annual quota of 125,000 lb was established and harvesting began in 1988.

There is considerable commercial potential for expanded harvests of geoducks and other species of clams in southeastern Alaska. However first, an easily administered

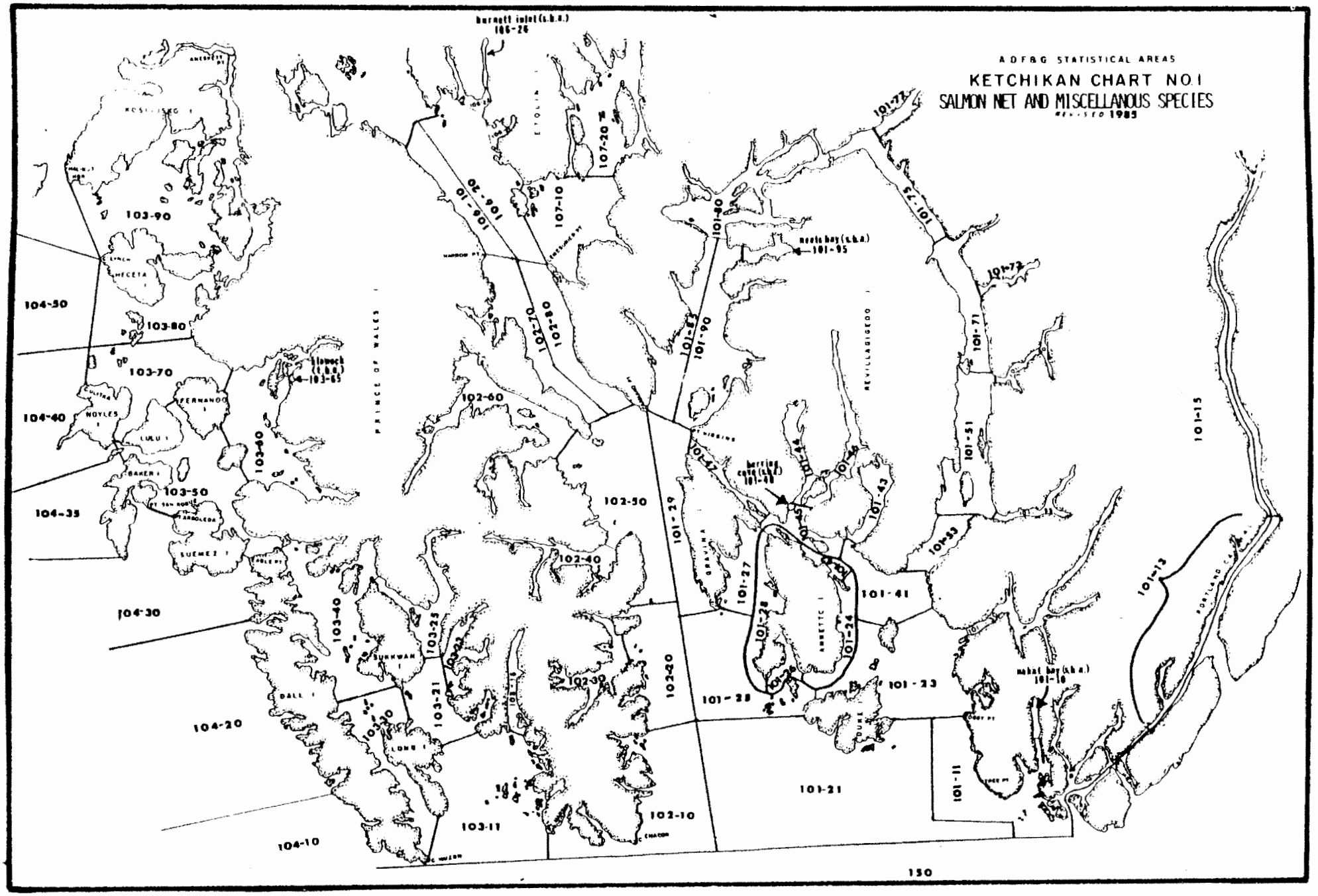

Figure 1. Alaska Department of Fish and Game commercial fisheries harvest statistical areas for Southern Southeastern Alaska.

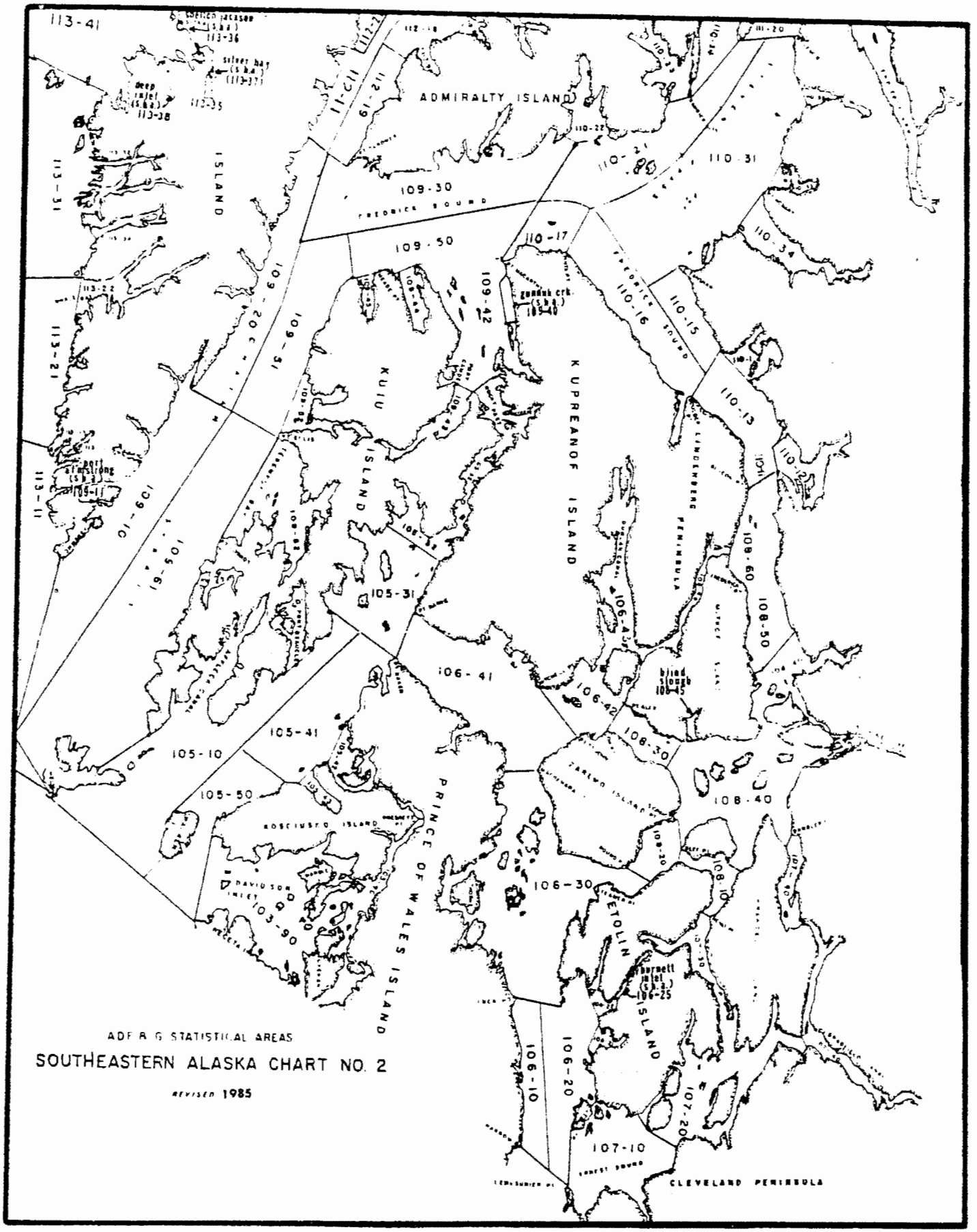

Figure 2. Alaska Department of Fish and Game commercial fisheries harvest statistical areas for Central Southeastern Alaska.

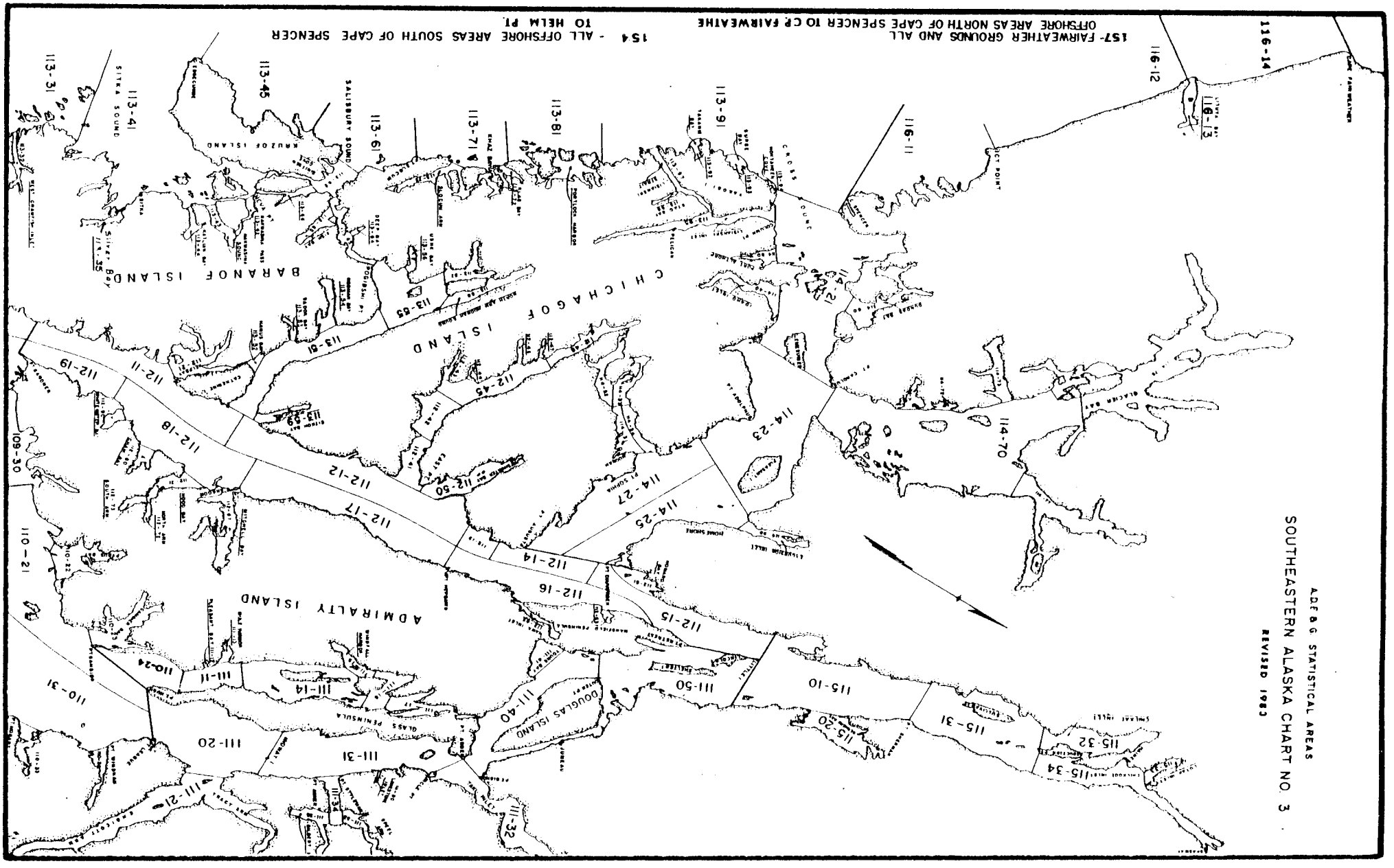

Figure 3. Alaska Department of Fish and Game commercial fisheries harvest statistical areas for Northern Southeastern Alaska.

and reliable test for PSP must be developed so that an unprocessed product can be marketed (T. Koeneman, pers. comm.).
Geoduck clams are harvested on a very limited scale by coastal residents for personal use. This harvest is limited to SCUBA divers. Other species of clams are commonly harvested for personal use in southeastern Alaska (Gmelch and Gmelch 1985): butter clams (*Saxidomus giganteus*), Pacific littleneck clams (*Protothaca staminea*), razor clams (*Siliqua patula*), cockles (*Clinocardium nuttallii*), surf clams (*Spisula polynyma*) and horse clams (*Tresus capax*).

It is not known if sea otters will have any impact on geoduck populations. I am aware of only one reference to sea otters feeding on geoducks. Rosenthal and Barilotti (1973) reported finding discarded geoduck shells in sea otter middens off west Chichagof Island in southeastern Alaska. Geoducks are found at depths less than 90 ft; most of them at less than 40 ft, which is well within the diving range of sea otters. It may be that geoduck clams are buried too deeply in the bottom to be easily obtained by otters.

Other species of clams commonly occur in the sea otters diet (Rosenthal and Barilotti 1973, Hines and Loughlin 1980, Garshelis et al. 1986, Johnson 1988). In some instances, sea otters have apparently been responsible for reductions in abundance of clam populations and size of individuals (Johnson 1982, Estes and VanBlaricom 1985, Miller et al. 1975, Wendell et al. 1986).

Sea Urchins

From 1981 through 1983 small quantities (3,754 lb) of urchins were marketed to evaluate the feasibility of commercial harvesting and exportation of roe, primarily to Japan. There was interest in both red and green sea urchins. Apparently, red urchins, which are larger, are more abundant and widespread; however the green sea urchin is preferred in some markets. In 1984 the first significant harvest occurred; 40,000 lb were marketed. In 1985, 1986, and 1987 about 126,000, 282,000, and 653,000 lb were harvested, respectively, and sold for about $0.20/lb. Primary harvest areas have been the Ketchikan area and waters off northern and western Prince of Wales Island.

The fishery has been managed through collection of harvest data from the fish ticket program and by issuance of the miscellaneous shellfish registration-permit form. A season of (1 October-31 January) and a size limitation (3.5-5.0 in) have been established. Because of very limited knowledge of the biology of these species in southeastern Alaska, management has been restricted almost entirely to limiting harvests in specific areas to low levels and then requiring

fishermen to move into other areas to prevent local depletion and to assist in the exploratory process.

Very limited harvests of sea urchins for subsistence purposes occur (Mills 1982, Gmelch and Gmelch 1985).

It has been well documented in numerous studies that sea urchins are (1) a major prey of sea otters, (2) among the first prey utilized when otters move into an area, and (3) reduced both in size and abundance by otter predation (Lowry and Pearse 1973, Estes and Palmisano 1974, Duggins 1980, Estes and VanBlaricom 1985). Rosenthal and Barilotti (1973) found that red sea urchins composed 83% of identifiable food items in sea otter middens off west Chichagof Island in southeastern Alaska. Soon after Surge Bay and Deer Harbor in southeastern Alaska had been repopulated by sea otters, Duggins (1980) found low densities of urchins (all of which were small and concealed under rocks); however, the bottom was littered with broken urchin tests, evidence of their past abundance.

To quote Estes and VanBlaricom (1985): "There can be little doubt that presence of sea-otters is incompatible with red urchin fisheries." Anywhere that otter populations become established in southeastern Alaska, urchin densities and size will likely be reduced to such levels that human utilization will be precluded.

Abalone

Commercial harvests of this species, which began in the early 1960's, were small (<20,000 lb) and variable until 1978 when 181,000 lb were marketed. A combination of factors, including a reduced supply of abalones on the world market, acceptance of the northern abalone in the Japanese market, favorable exchange rates for the yen, and liberal harvest regulations, resulted in greatly increased harvests. From 1978 through 1980 the annual harvest of abalones in southeastern Alaska averaged about 262,000 lb. Since that time harvests have declined to much lower levels: about 76,000 lb, 54,000 and 63,000 lb in 1985, 1986 and 1987, respectively. With prices of about $3.10/lb the ex-vessel value of the fishery ranged between $167,000 and $235,000 for the past 3 years. The decline in harvest can be attributed to more restrictive regulations as well as reduced abundance of legal-sized abalones. The early, large harvests were probably taken from climax populations with many old and large individuals. Currently, it is primarily a recruit-based fishery probably complicated by low and sporadic recruitment. Southeastern Alaska is the extreme northern limit of the range of the species, and environmental conditions suitable for successful reproduction and survival may only occur sporadically.

Management strategies developed for the commercial fishery include a closed season during the spawning and settling season, a minimum legal size to retain some sexually mature individuals in the population, harvest quotas, and area closures.

Some residents of communities near the outside coast harvest abalones for subsistence purposes. Hydaburg, Craig, Klawock, Sitka, Ketchikan, Metlakatla, Elfin Cove, and Pelican are notable among the towns and villages with active abalone harvesters (Mills 1982). The amount of abalone actually consumed by these subsistence users is not great; however, it is a highly valued item often eaten on special occasions (Mills 1982). Most of the harvest occurs within close proximity to these towns, normally within 30 miles. The subsistence fishery is regulated by a minimum size limit (3 in, except 3.5 inches in district 113) and a daily bag limit (50).

Northern abalones inhabit rocky areas with an ocean swell influence and are usually found at depths <50 ft. They are found primarily along the outside coast of southeastern Alaska, and 97% of the commercial harvest between 1975 and 1984 was taken from statistical areas 103, 104, and 113 (Table 1, Figures 1-3).

Table 1. Magnitude and ex-vessel value (based on $2.90/lb) of the commercial abalone harvest by district in southeastern Alaska, 1976-1985.

District	Lb	Value ($)	Rank
101	7,886	22,869	5
102	5,519	16,005	7
103	505,931	1,467,200	3
104	774,385	2,245,717	1
105	26,977	78,233	4
106	0	0	10
107	0	0	10
108	0	0	10
109	6,038	17,510	6
110	0	0	10
111	108	313	9
112	0	0	10
113	512,453	1,486,114	2
114	296	858	8
115	0	0	10
All Areas	1,839,593	5,334,820	

Sea otters are known to prey on abalones, particularly in California (Hall and Schaller 1964, Ebert 1968, Hines and Pearse 1982). Abalones have also been recorded as a prey of otters in southeastern Alaska (Rosenthal and Barilotti 1973). It is not possible to evaluate the impacts that expanding sea otter populations may have had on the commercial abalone fishery in southeastern Alaska because of (1) the newness of the fishery, (2) the large scale exploitation that initially occurred, (3) annual variations in quotas, season lengths and area closures, and (4) the large size of the harvest reporting areas. Estes and VanBlaricom (1985) concluded that in California there was little doubt but that sea otters had eliminated or hastened the decline of some abalone fisheries. It appears probable that significant abalone fisheries will not persist in areas of southeastern Alaska in which sea otters become established.

Dungeness Crab

Commercial harvests of this species in southeastern Alaska have averaged about 1.1 million lb annually since 1960, ranging between 124,000 lb and 4 million lb. Between 1976 and 1985 annual harvests averaged 1.3 million lb (Table 2). Based on the 1983-84 average price of $1.15/lb, the average annual ex-vessel value of this fishery between 1976 and 1985 was 1.59 million dollars. Historically, commercial demand for Alaskan dungeness crab has depended on the availability of crab from California, Oregon, and Washington. During years when crabs were abundant in these states prices paid to Alaskan fisherman were not high enough to stimulate a large effort. During the late sixties and seventies when catches were high to the south, Alaskan dungeness crab stocks were not fully exploited. Currently all available fishing grounds in southeastern Alaska are fully utilized, and since 1981 annual harvests have averaged about 2.25 million lb. In 1987 the harvest was 3.2 million lb with an ex-vessel value of about 4 million dollars. Only males >6.5 inches in shoulder width can be legally harvested. Closed seasons occur during segments of the molting and mating seasons.

In southeastern Alaska dungeness crabs are found and harvested primarily in bays with mud or sand bottoms, generally at depths less than 15 fathoms. Harvest of dungeness crabs occurs nearly exclusively within the inside waters of southeastern Alaska. Between 1976 and 1985 only 1% of the total commercial harvest came from outside waters (Districts 103, 104, and the outside portion of 113; Figures 1-3). Five of the 15 districts produced 73% of the harvest: districts 105 and 106, the Sumner Strait area; 108, the Wrangell-Stikine River area; 112, upper Chatham Strait; and 114, the Icy Strait-Cross Sound area.

Crabbing is one of the most common subsistence resource harvesting activities in southeastern Alaska (George et al. 1985), and dungeness crab is the most commonly harvested species. An estimated 55% of the households in predominantly Native communities and 71% of the households in small, non-Native communities participated in subsistence crabbing. Residents of small communities may obtain up to 5% of their meat supply from crab (Schroeder and Nelson 1983). Most subsistence crabbing occurs relatively close to communities, particularly in sheltered bays that can be reached in small boats. A partial catalog of subsistence dungeness crabbing sites for southeastern Alaska is presented in George et al. (1985). ADF&G regulations provide a subsistence priority around several communities through reduced commercial seasons and area closures to commercial crabbing.

Table 2. Magnitude and ex-vessel value ($1.15/lb) of the commercial dungeness crab harvest by district in southeastern Alaska, 1976-1985.

District	Lb	Value ($)	Rank
101	447,014	514,066	10
102	22,151	25,474	14
103	60,561	69,645	13
104	8,155	9,378	15
105	1,119,526	1,287,455	4
106	2,679,668	3,081,618	2
107	751,636	864,381	7
108	2,374,243	2,730,379	3
109	616,257	708,696	9
110	738,361	849,115	8
111	112,464	129,334	11
112	1,057,973	1,216,669	5
113	899,602	1,034,542	6
114	2,871,123	3,301,791	1
115	73,038	83,994	12
All Areas	13,831,772	15,906,538	

The only area for which dungeness crabs have been reported as an important prey of sea otters is Prince William Sound, Alaska (Garshelis et al. 1986, Johnson 1988). Except for southcentral Alaska, sea otters have not been abundant within the primary range of dungeness crabs in recent times. Most food habit studies have been conducted in California (south of Monterey Bay) and the Aleutian Islands where dungeness crabs are not abundant. As sea otter populations expand into areas supporting large dungeness crab stocks, they may be shown to be an important food item.

The only reasonably good information on the impacts of sea otter predation on dungeness crab populations comes from the Orca Inlet area of Prince William near Cordova, Alaska. Observations in nearby Nelson Bay indicated that adult otters consumed an average of 14 crabs/day, while subadults took 10 crabs/day (Garshelis et al. 1986); over 50% of these crabs were of commercially harvestable size. Surveys indicated a substantial decline in the abundance of crab after the arrival of large numbers of otters, and it was concluded that otter predation had a major impact on crab numbers (Garshelis et al. 1986). This large influx of sea otters into the Orca Inlet-Nelson Bay area was followed by a >80% decline in the density of dungeness crabs and a closure of crab fishing (Garshelis and Garshelis 1984). Based on this evidence, Estes and VanBlaricom (1985) concluded that there might be the potential for a substantial conflict between sea otters and the dungeness crab fishery along much of the west coast of North America.

Should sea otters move into the inside waters of southeastern Alaska where most of the dungeness crab fishery occurs, it is conceivable that a serious conflict could develop. Most of this fishery takes place in shallow waters (<15 fathoms), which is well within the sea otters feeding range. It is felt by shellfishery biologists that most of the dungeness crab population is present in shallow water, at least seasonally (T. Koeneman, pers. comm.), so they would be readily available as prey. Residents of Elfin Cove, in northern southeastern Alaska, indicated to me that dungeness crabs are no longer abundant in nearby Port Althorp since sea otters moved into the area. For the decade 1976-1985 the dungeness fishery was second only to tanner crab as the most valuable shellfishery in southeastern Alaska. During recent years (1985-87) the dungeness fishery has been by far the most valuable, with a harvest twice that of tanner crabs.

Tanner Crab

Both the size and value of harvests for this species were the largest of any shellfishery in southeastern Alaska during the period 1976-1985 (Table 3). The average annual harvest and ex-vessel value was about 1.8 million lb and 1.9 million dollars (at $1.05/lb), respectively. During this period annual harvests have ranged between 1 and 2.5 million lb. This fishery did not develop in Southeastern until the early 1970's because of low prices due to preference for other species. Harvests peaked from the mid-1970's to 1982 with some years exceeding 2 million lb. Currently, it is thought that all significant stocks of tanner crabs in southeastern Alaska are being fully exploited.

Four districts (110, lower Stephens Passage; 111, Stephens Passage; 114, Cross Sound-Icy Strait; 115, Lynn Canal)

produced 84% of the harvest between 1976 and 1985. In recent years there has been a trend of increasing harvests in districts 111 and 115 and decreasing harvests in district 114, the latter an apparent reflection of reduced crab availability. The Southeastern tanner crab harvest is nearly entirely restricted to inside waters. Only 1% of the harvest during the decade 1976-1985 occurred along the outside coast in districts 103, 104, and the outside portion of 113. The fishery occurs primarily in bays in northern and central, southeastern Alaska at depths of 30 to 75 fathoms. Tanner crabs concentrate in shallow water seasonally; December through early summer (T. Koeneman, pers. comm.).

Table 3. Magnitude and ex-vessel value ($1.05/lb) of the commercial tanner crab harvest by district in southeastern Alaska, 1976-1985.

District	Lb	Value ($)	Rank
101	14,896	15,641	13
102	0	0	15
103	17,253	18,116	12
104	12,626	13,257	14
105	102,241	107,353	11
106	520,990	547,040	7
107	142,127	149,233	10
108	841,213	883,274	5
109	228,412	239,833	9
110	2,008,739	2,109,176	3
111	4,603,868	4,834,061	2
112	493,305	517,970	8
113	541,330	568,397	6
114	7,484,727	7,858,963	1
115	1,174,133	1,232,840	4
All Areas	18,185,860	19,095,153	

Management of this fishery currently involves a 1-million-lb annual quota and an open season from 15 January through 1 May. In 1987 the quota was reached and season closed on 17 February. Only male crabs with a shell width of 5.5 in or greater can be legally harvested. The fishery is primarily recruit dependent, and there is little annual carryover of legal-sized crabs.

Tanner crabs are harvested by subsistence users, although to a lesser extent than dungeness crabs (George et al. 1985). This is probably due to their more restricted geographic distribution and there tendency to inhabit deeper water and areas more exposed to inclement weather.

Tanner crabs have been reported as a food item of sea otters (Kenyon 1969; Johnson 1988; ADF&G unpubl. data) but have never been found to be a major prey. There is no evidence to indicate that tanner crab populations have been impacted by otter predation or that conflicts with fisheries have occurred. However, because (1) they concentrate seasonally in shallow water, (2) are known to be eaten by sea otters, and (3) appear to be an energetically profitable prey, there appears to be potential for conflicts to develop should the distribution of tanner crabs and sea otters overlap in southeastern Alaska.

Red King Crab

Blue king crabs are very limited in abundance and distribution in southeastern Alaska and are biologicaly similar to red king crabs. Therefore the are included with red king crabs in this report. The commercial fishery for these species, which developed during the 1960's, harvested an average of about 360,000 lb annually during 1976-1985 (Table 4). Since 1986 the fishery has been closed because of depressed stock levels. Based on the average price of $3.90/lb during 1983 and 1984, the average annual ex-vessel value of this fishery was about 1.3 million dollars, nearly the equivalent value of the much larger harvests of dungeness and tanner crabs.

Table 4. Magnitude and ex-vessel value ($3.60/lb) of the commercial red king crab harvest by district in southeastern Alaska, 1976-1985.

District	Lb	Value ($)	Rank
101	4,437	15,973	12
102	0	0	14
103	2,616	9,418	13
104	0	0	14
105	34,824	125,366	9
106	32,718	117,785	10
107	21,114	76,010	11
108	64,587	232,513	8
109	94,720	340,992	7
110	872,920	3,142,512	2
111	974,442	3,507,991	1
112	257,656	927,562	5
113	668,698	2,407,313	3
114	425,700	1,532,520	4
115	202,436	728,770	6
All Areas	3,656,868	13,164,725	

The commercial red king crab harvest occurs nearly exclusively in the northern portion of southeastern Alaska. Three districts (110, eastern Frederick Sound and lower Stephens Passage; 111, Stephens Passage and Seymour Canal; and the inside waters of 113, the Hoonah Sound area) were particularly important, producing 69% of the harvest during 1976-1985.

Guideline harvest levels for the fishery are based on ADF&G stock index surveys. The fishing season of 1 September through 31 January was established to afford protection during the congregation period, the major growth period, and the molt and mating seasons. Only male crabs with a carapace width of at least 7.0 in can be legally harvested.

King crabs are also harvested by subsistence users, primarily in northern southeastern Alaska, although to a lesser extent than dungeness crab (George et al. 1985). Their distribution is more limited and they often occur in deeper water, making them less accessible for most subsistence harvesters. King crab harvesting requires pots that are heavier, more expensive, and harder to handle than dungeness gear (Leghorn and Kookesh 1987). Maps showing some subsistence king crabbing areas are included in George et al. (1985).

Red king crabs are generally fished in protected bays and inlets at depths of less than 150 fathoms. They occur in shallow water within the diving range of sea otters from December through early summer (T. Koeneman, pers. comm.). Females and juvenile males probably occur in shallow water more frequently than adult males.

As with tanner crabs, king crabs have been reported as a prey of sea otters (Johnson 1988; Kenyon 1969; ADF&G unpubl. data) although not as comprising a major portion of the diet. No reports are available indicating that sea otters have had an adverse impact on king crab populations. If eventually red king crab and sea otter distributions overlap in southeastern Alaska and should otters key in on shallow-water concentrations of king crabs as a seasonal food source, they could conceivably reduce abundance and compete with human utilization.

Geographic Distribution of Southeastern Alaska Commercial Shellfish Harvests

In order to identify those areas of southeastern Alaska that have the highest total economic value for the commercial harvest of those species of shellfish that are being fully exploited and are most likely to be impacted by sea otter predation, I summed the values of the abalone, dungeness crab, tanner crab, and red king crab harvests (Tables 1-4)

for the 15 districts (Table 5). Because the size of the districts vary substantially, I was concerned that the total value for each district might be a reflection of the size of the district rather than an indication of concentrations of shellfish resources. In order to evaluate this concern, rough estimates of area were made for each district and then each district was ranked according to total value/area (Table 5). Rank according to total value was then compared to rank according to total value/area of the district, using Spearman's Rank Correlation Coefficient. The two rankings were in substantial agreement ($r_s = 0.81$, $P < 0.01$). This supported the validity of using total value of the harvest as an indicator of the importance of the shellfish resources between districts. Three districts (110 , Stephens Passage; 111, eastern Frederick Sound; and 114, Cross Sound and Icy Strait) were particularly important; when combined they represented 51% of the total value. Districts 110 and 111 were the major king and tanner crabs producers, while district 114 had the largest harvests of dungeness and tanner crabs in the region.

Table 5. Total value by district of commercial harvest of selected shellfish species, 1976-1985.

District	Total value($)	Rank by value	Area (mi^2)	Value/ Area	Rank by Value/area
101	568,550	14	1,686	337	14
102	41,479	15	585	71	15
103	1,564,378	11	1,100	1,422	11
104	2,268,352	8	2,310	982	12
105	1,598,408	10	678	2,358	9
106	3,746,442	6	681	5,501	5
107	1,089,625	13	279	3,905	7
108	3,846,166	5	385	9,990	3
109	1,307,030	12	1,413	925	13
110	6,100,803	3	895	6,817	4
111	8,471,699	2	841	10,073	1
112	2,662,201	7	932	2,856	8
113	5,496,365	4	3,389	1,622	10
114	12,694,133	1	1,266	10,027	2
115	2,045,603	9	428	4,779	6
Totals	53,501,235		16,868	3,172	

The northern portion of southeastern Alaska (Districts 109-115) produced 71% of the total value, largely because most of the tanner and king crab as well as about half of the dungeness crab harvest occurred in that area. Conversely, the southern districts (101-108) produced 72% of the abalone harvest.

The distribution of commercially harvested abalones and dungeness, red king, and tanner crabs in relation to the exposed, outside coast of southeastern Alaska was striking (Table 6). Commercial abalone harvests occurred nearly exclusively along the outside coast, while the opposite was true for the three crab species which were harvested primarily in the more protected, inside waters. This is thought to accurately reflect the distribution of these species because they are being fully exploited in the southeastern Alaska fisheries (T. Koeneman, pers. comm.).

Currently, sea otter distribution (Figure 4) in southeastern Alaska is mostly limited to portions of the outer coastline, although some animals have moved into Sumner Strait and Cross Sound (Pitcher 1987). It is expected (Johnson et al. 1983) that the outer coastline will eventually become continuously populated from Dixon Entrance to well north of Cape Spencer. The extent to which sea otters will populate the inside waters of southeastern Alaska is unclear. Kenyon (1969) found no record that otters ever occurred in the inland waters of southeastern Alaska and assumed that they were distributed only along the outside coast. Sea otter bones were reported as prevalent in middens at Native village sites near Angoon located in the inside waters of Chatham Strait (Vequist 1987 citing de Laguna 1960). The locations where these otters were harvested are unknown but it is possible that they came from inside waters. Sea otters are distributed throughout the inside waters of Prince William Sound, a somewhat comparable situation to southeastern Alaska. There appear to be no physical or biological barriers to prevent otters from occupying inside waters.

Table 6. Proportion of commercial shellfish harvest which occurred along the outside coast (districts 103, 104 and outside portion of 113), 1976-1985.

Species	Outside harvest(lb)	Outside value($)	Total value($)	%Total value
Abalone	1,782,753	5,169,983	5,334,820	97
Dungeness Crab	471,010	541,662	15,906,538	1
Red King Crab	70,787	254,833	13,164,725	2
Tanner Crab	148,466	155,889	19,095,153	1
Totals	2,473,016	6,122,367	53,501,236	11

The future distribution of sea otters in southeastern Alaska has major implications regarding potential conflicts between otter and human utilization of shellfish. Abalones, which occur primarily along the outside coast in areas influenced by ocean swells, appear to be particularly vulnerable to

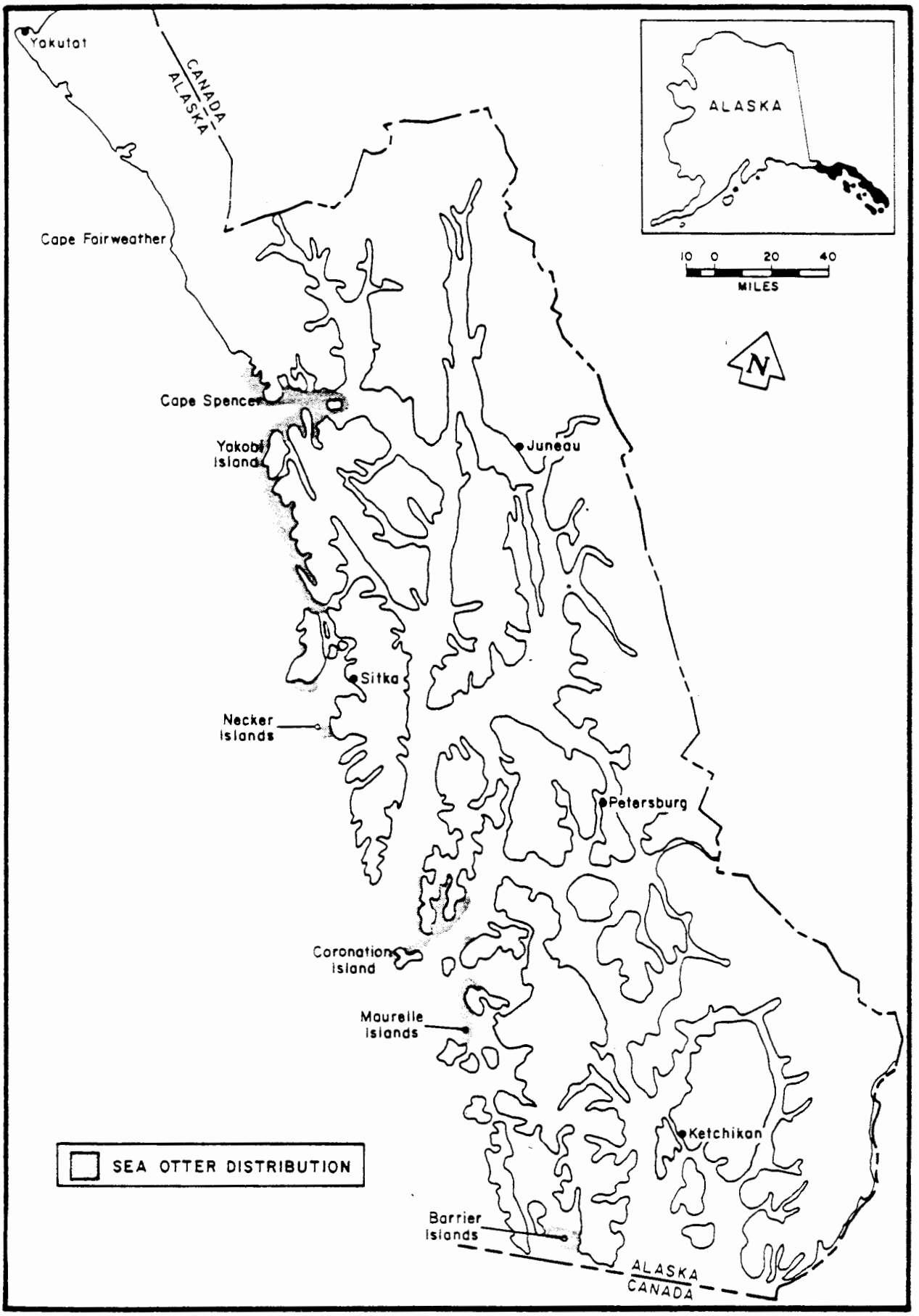

Figure 4. Distribution of sea otters in Southeastern Alaska, June and July 1987.

otter predation. Much of the harvest in recent years has come from areas that have not yet been fully populated by otters, including Dall, Lulu, Baker, and Sumez Islands, the Gulf of Esquibel, Sea Otter Sound, southeastern Sumner Strait, and southwestern Baranof Island. All of these areas are likely to eventually support substantial otter populations, and abalone abundance will probably be reduced, perhaps, to the point that human utilization will become insignificant.

A fishery which is developing on red sea urchins will almost certainly be limited by sea otter predation. Red urchin distribution appears to favor areas influenced by ocean swells; most of these areas will probably be occupied by otters. Harvestable populations of green sea urchins, which favor more protected waters, may persist in some areas, depending on the extent of colonization of inland waters by sea otters.

Much of the range of geoduck clams, which also favor the outer coast, will likely be eventually occupied by sea otters. However the extent to which sea otters will prey upon and impact geoducks is unknown.

The dungeness crab fishery occurs nearly exclusively in inside waters where few otters now occur; however, 2 important dungeness fishing districts are areas in which otters appear to be colonizing inland waters. These are districts 105 in western Sumner Strait and 114 in the Cross Sound-Icy Strait area. Other major dungeness districts are 106, eastern Sumner Strait; 108, the Wrangell area; and 112, upper Chatham Strait. The latter two are well inland and will probably not have high otter densities for many years, if at all. It appears that otters have the capability, at least in some situations, to drastically reduce dungeness crab abundance. The potential appears to exist for serious sea otter-dungeness crab fishery conflicts to develop in southeastern Alaska.

The situation is much less clear for red king crabs and tanner crabs. Neither species has been documented as a major prey of sea otters, nor have fishery conflicts been reported. Both species occur seasonally in shallow water within the feeding range of otters and would appear to be suitable prey. Excepting district 114, the primary harvest areas (Tables 3 and 4) are well inland and likely will not have high otter densities for many years, if ever.

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