IMPACTS OF SEA OTTER PREDATION ON DUNGENESS CRAB ABUNDANCE IN THE CROSS SOUND-ICY STRAIT AREA, SOUTHEASTERN ALASKA

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PREFACE

In September 1986 the U.S. Fish and Wildlife Service contracted with the Alaska Department of Fish and Game to conduct studies of reintroduced sea otter (*Enhydra lutris*) colonies in southeastern Alaska. It was recognized that these expanding populations probably had the potential to adversely impact certain shellfish populations that were being exploited in commercial and personal-use fisheries. Sea otters in southeastern Alaska were also the target of an unregulated harvest by Alaska Natives, as provided for under the Marine Mammal Protection Act. There was an obvious need for information on sea otter distribution, abundance, population growth, and range expansion as well as information on shellfish populations and fisheries, locations of important shellfish harvest areas, and the impacts of sea otter predation on shellfish populations.

A previous 2-part report (Pitcher 1989) partially fulfilled contractual obligations. Part I reported on the findings of surveys (1987 and 1988) on sea otter colonies throughout southeastern Alaska, including information on productivity and range expansion. Part II was a review and synthesis of historical harvest records of shellfisheries in southeastern Alaska that had the potential to be negatively impacted by sea otter predation. Important shellfish harvest areas were identified and the relative commercial values of their respective fisheries were presented. This report (Part III) presents results of a study designed to evaluate the impacts of predation by a colonizing population of sea otters on dungeness crab populations in the Cross Sound-Icy Strait area of southeastern Alaska; it also [illegible]ces requirements of the interagency contract.

INTRODUCTION

Dungeness crabs (*Cancer magister*) are one of the most important species of shellfish in the commercial and personal-use fisheries of southeastern Alaska (Pitcher 1989). They have also been reported as an important prey of sea otters (*Enhydra lutris*) in Prince William Sound, Alaska (Garshelis et al. 1986, Johnson 1988). Dungeness crabs generally occur in shallow waters within the feeding range of sea otters and are large, calorically rich food items (Garshelis et al. 1986). Adult sea otters in the Orca Inlet area of Prince William Sound consumed an average of 14 crabs/day, while subadults took 10 crabs/day (Garshelis et al. 1986). Surveys indicated a substantial decline in abundance of crabs after the arrival of large numbers of sea otters, and it was concluded that sea otter predation had a major impact on crab numbers (Garshelis et al. 1986). This large influx of sea otters into the Orca Inlet area was followed by a >80% decline in the density of dungeness crabs that necessitated closure of the crab fishery (Garshelis and Garshelis 1984).

Although sea otters appear to be colonizing inland waters in Sumner Strait, lower Chatham Strait, and the Cross Sound-Icy Strait area (Pitcher 1989), their distribution in southeastern Alaska is primarily limited to the outer coast (Figure 1). The historical distribution and abundance of sea otters in the inside waters of southeastern Alaska has not been clearly established. Because Kenyon (1969) was unable to find records to substantiate the occurence of sea otters in the inland waters of southeastern Alaska, he assumed that they were distributed only along the outer coast. Sea otter bones were prevalent at Native village sites near Angoon, which is located in the inland waters of Chatham Strait (Vequist [1987] citing de Laguna [1960]). While this is not definitive evidence that historical sea otter distribution included inland waters, it raises that possibility. Sea otters are well established throughout the inside waters of Prince William Sound, whose area is somewhat comparable to that of southeastern Alaska.

Both dungeness crabs and associated fisheries in southeastern Alaska are largely limited to inside waters. Only 1% of the commercial harvest between 1976 and 1985 occurred along the outer coast (Pitcher 1989). Important harvest areas include Sumner Strait, the Wrangell-Stikine River area, upper Chatham Strait, and the Cross Sound-Icy Strait area.

The continuing colonization of inland waters by sea otters, particularly Sumner Strait and the Cross Sound-Icy Strait areas, may potentially generate conflicts with the dungeness crab fishery. Because of these incursions, we need to know precisely what impacts sea otters will have on dungeness crab populations. Any serious considerations for managing sea otters and shellfish will require knowledge of the effects of sea otter predation on prey populations that are valued by humans.

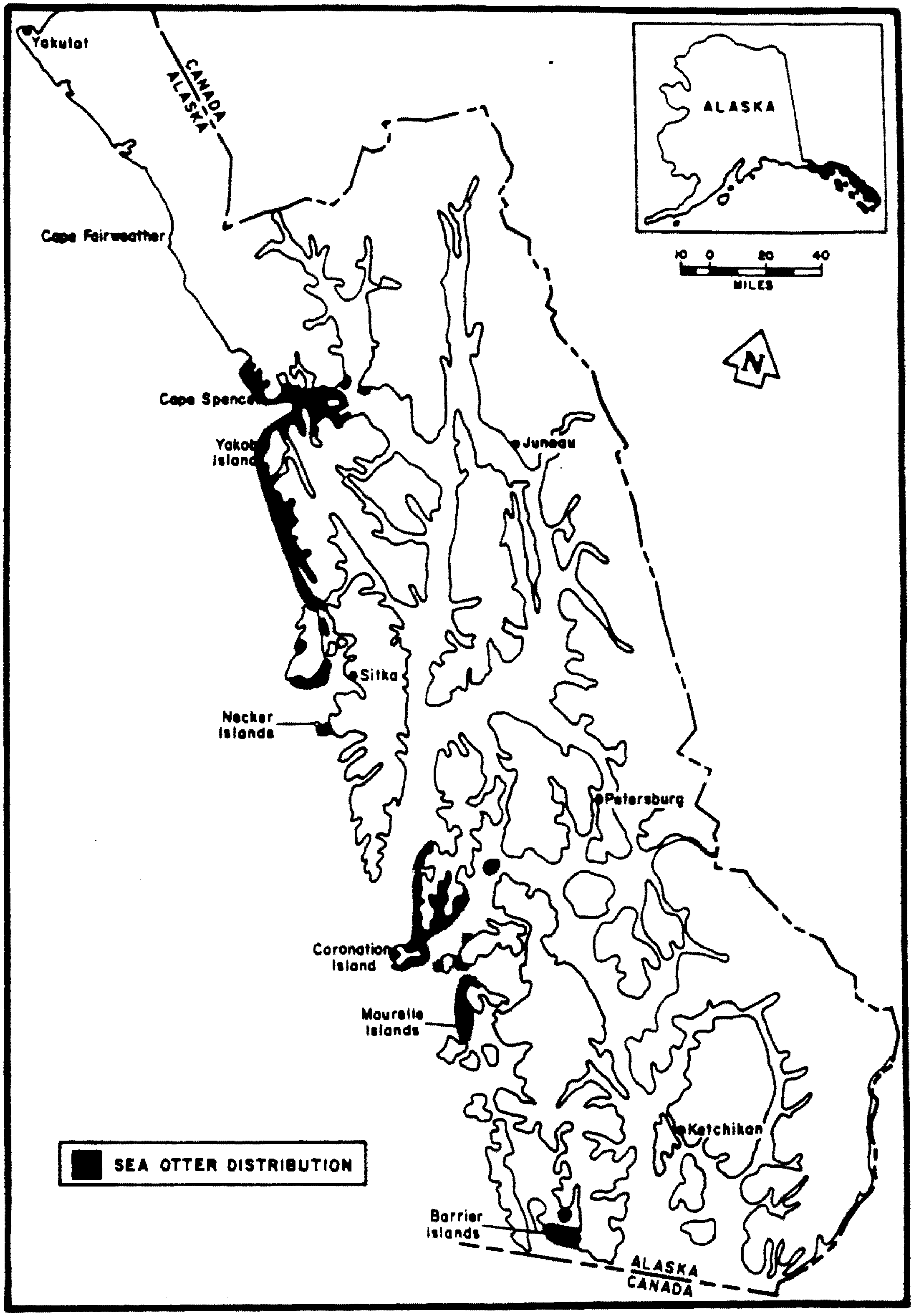

Figure 1. Distribution of sea otters in Southeastern Alaska, 1987 and 1988.

Based on the findings of sea otter surveys conducted during the summer of 1987, the Cross Sound-Icy Strait area was in the process of being colonized by sea otters (Pitcher 1987). Because this area has been one of the top producers of dungeness crabs in southeastern Alaska (i.e., accounting for about 21% of the total harvest during the period 1976 to 1985), it provided the opportunity to learn what effects an expanding sea otter population would have on local dungeness crab stocks. A program was envisioned in which the abundance and distribution of sea otters and dungeness crabs would be monitored annually through skiff surveys and test-fishing, respectively. Multiple test-fishing sites would be established in areas where sea otters would likely become established (i.e., experimental) and in areas likely to remain unpopulated in the near future (i.e., control). The abundance of dungeness crabs could then be compared over time at each site. Consultations were held with T. M. Koeneman and K. K. Imamura, shellfish biologists with Alaska Department of Fish and Game (ADF&G), regarding the feasibility of obtaining reliable indices of dungeness crab abundance through a test-fishing program. They suggested that a sampling design similar to one developed for their red king crab (*Paralithodes camtschatica*) assessment surveys would be appropriate. We then developed a cooperative program to evaluate impacts of sea otter predation on dungeness crabs; K. W. Pitcher assumed responsibility for monitoring otter distribution and abundance in the study area, while K. K. Imamura assumed responsibility for designing, conducting, and analyzing data from the dungeness crab abundance surveys.

The proof of our hypothesis (i.e., that sea otter predation on dungeness crabs will significantly reduce crab abundance) will occur when the catch per unit effort (CPUE) values for crabs decline significantly at the test-fishing sites inhabited by sea otters, relative to sites where they have not become established. Additional insight may be obtained by comparing CPUE rates between test fishing sites, relative to length occupancy and density of sea otters.

METHODS

Sea otter surveys were conducted from 16- and 19-foot Boston Whaler skiffs. Two observers occupied each skiff; one recorded the observations and the other one operated the skiff. The shorelines of islands, as well as the mainland and offshore rocks and kelp beds, were searched from the skiffs. On occasions when sea otters had been observed offshore, transects were run with the skiffs. Binoculars were used as an aid in counting animals. When large numbers of sea otters were encountered, we attempted to place an observer onshore to count them with binoculars or a spotting scope. Most surveys were conducted between 0800 and 1700 hours, when the proportion of animals resting on the surface is normally highest. On occasions when weather conditions were very good, surveys were extended for several hours. The sites frequented by sea otters, as well as the adjoining ones, were arbitrarily divided into count areas. Data recorded included total number of sea otters observed, number of dependent pups, locations of sightings, activity of the otters, weather conditions, and date and time of sightings. Survey quality was subjectively classified as excellent, good, fair, poor, or bad, based on impressions of visibility and thoroughness of coverage.

Seven locations (Figure 2) in the Cross Sound-Icy Strait area were selected as dungeness crab abundance index sites (test fishing sites). Those sites and the rational for their selection are as follows:

1. The head of Port Althorp was selected as an experimental area; it had once produced commercial catches of dungeness crabs (Table 1) before its designation as a subsistence fishing area and closure to commercial fishing in 1983-84. Sea otters were first noted in Port Althorp in 1983 (Johnson et al. 1983) and have subsequently been observed during all surveys covering that area (Simon-Jackson and Hodges 1986, Pitcher 1989).

Table 1. Average annual commercial harvest of dungeness crabs between 1978-79 and 1988-89 at index survey sites in the Cross Sound-Icy Strait area.

Area	Average harvest (lb)
Port Althorp	1,180
Idaho Inlet	5,212
Gustavus Flats-Mud Bay	95,006
Beardslee Islands	151,238
Dundas Bay	9,297

2. The head of Idaho Inlet was selected as an experimental area with an ongoing commercial harvest of dungeness crabs (Table 1). No sea otters were observed in this area during surveys conducted in 1987 or 1988 (Pitcher 1989); however, substantial numbers of them were observed from the mouth to the middle of the bay. During 1989 sea otters were observed about two-thirds of the way into the bay, and it is likely that the entire bay will be occupied within the next several years.

3. The mouth of Idaho Inlet was selected as an experimental area that has also produced moderate commercial catches of dungeness crabs (Table 1). This is an area that is believed to have been recently populated by sea otters. Otters were first observed there in July 1987 (Pitcher 1989); however, previous surveys did not include the area. It was dropped as a crab index

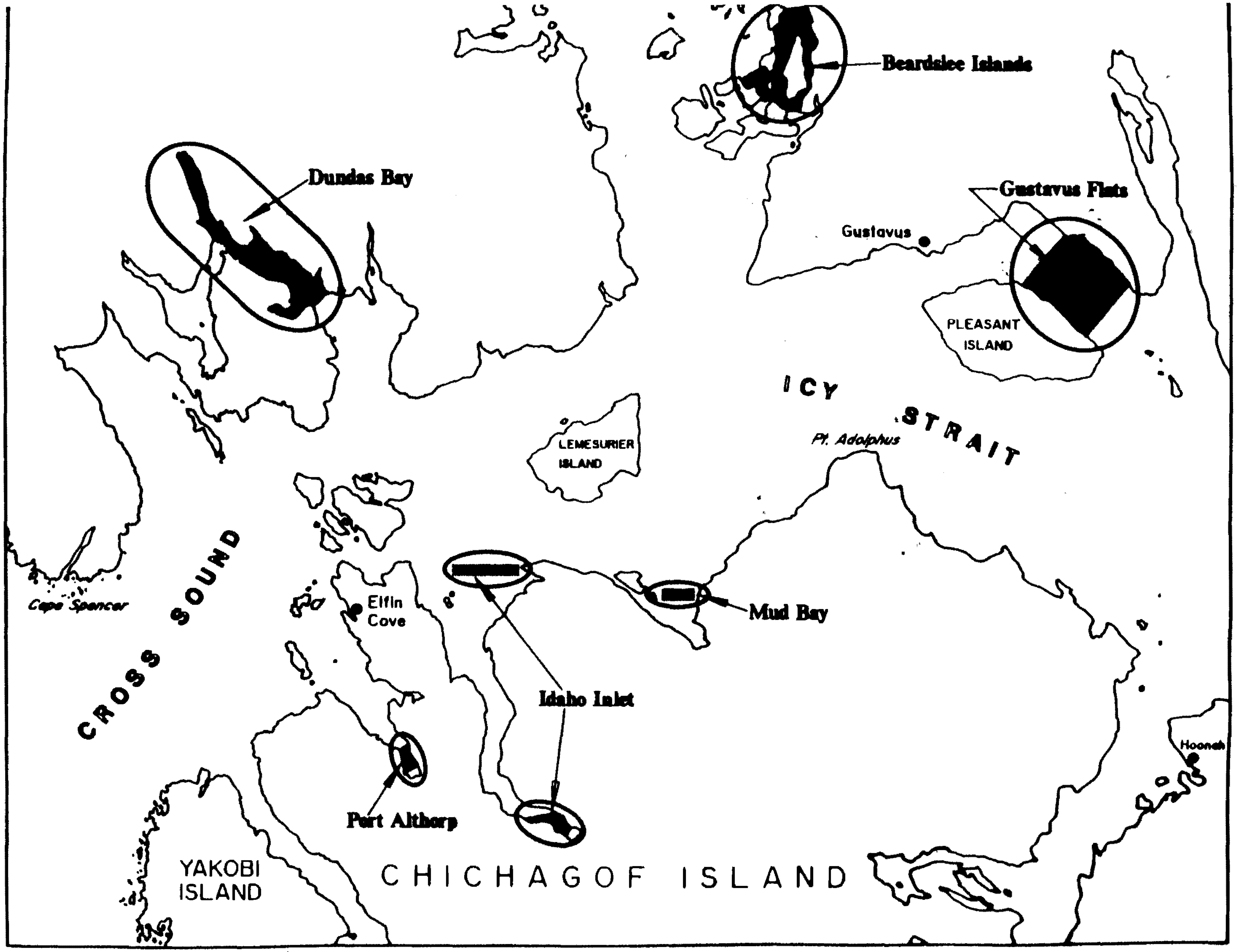

Figure 2. Dungeness crab test fishing index sites in the Cross Sound/Icy Strait area during 1988 and 1989.

site in 1989 because of sampling difficulties (limited habitat at appropriate depths) encountered during the previous year.

4. Mud Bay was selected as an experimental area that produces low-to-moderate commercial catches of dungeness crabs (Table 1). It appears that Mud Bay is being colonized, because small numbers of sea otters were observed on the western periphery of the area during surveys in 1987 and 1988 (Pitcher 1989). It is possible that Mud Bay will contain substantial numbers of sea otters within the next few years.

5. Gustavus Flat, located between the Gustavus forelands and Pleasant Island, was selected as a control area. It is a productive commercial (Table 1) and personal-use fishing area that is essentially unpopulated by sea otters. On occasion, small numbers have been seen at Point Gustavus on the western edge of the Flat (Vequist 1987, Pitcher 1989). Because the area is distant from large concentrations of sea otters, it is not expected to be populated within the next few years. Gustavus Flat was not sampled in 1989 so that the promising experimental site at Dundas Bay could be included.

6. The vicinity around the Beardslee Islands in Glacier Bay was chosen as a control area. These bays and estuaries are an extremely productive commercial (Table 1) and personal-use fishing ground for dungeness crabs. No sea otter sightings have been reported there. Sea otters will not colonize this area in the near future, because of its remote and protected inland location.

7. The productive fishing area of Dundas Bay was added to the sampling sites in 1989 (Table 1). Sea otters were first observed there in 1989, when 40 were counted; they are in the early stages of colonizing the area.

Standard commercial dungeness pots were used for sampling. These 50- to 80-pound pots have frames constructed of steel reinforcing bar (rebar) wrapped with rubber; they are covered with stainless steel mesh. The rings sewn into the pots to permit the escape of smaller female and sublegal male crabs were wired shut to maximize retention of smaller crabs.

The sampling periods were from 30 May to 4 June 1988 and 23 to 27 May 1989. These dates preceded the commercial season, which began 15 June. Dungeness crabs are active and susceptible to capture in pots during this period. A commercial dungeness crab fishing vessel (F/V Adeline) was chartered to conduct the test fishing. Otto Florschutz, the captain of the vessel, was selected because of his experience fishing in the study area.

Fifty pots were fished at each of the index sites, except for the mouth of Idaho Inlet in 1988 (25 pots), Port Althorp in 1989 (10 pots), and Mud Bay in 1989 (41 pots). All sites had either been previously fished by Mr. Florschutz or productive for other fishermen. Each pot was baited with a combination of chopped squid and herring in 1988 and chopped herring in 1989. Pots were fished between 1200 and 2000 hours. The relative location of each pot was recorded on an overlay map of the area. In addition, loran readings of latitude and longitude of each set and the depth of water were recorded. Maps of dungeness crab sampling locations are on file with ADF&G, Divisions of Commercial Fisheries and Wildlife Conservation.

When each pot had been retrieved, crabs were sorted by species. Dungeness and incidentally caught tanner crabs (*Chionocoetes bairdi*) were sexed, measured, and graded for shell condition. Shell measurements were taken anterior of the tenth anterolateral spine, which is the standard location for carapace width measurements for dungeness crabs. Females were examined for stage of maturity and presence of eggs. If eggs were present, their stage of development, relative condition, and percent clutch fullness were recorded. Comments on parasites or other unusual conditions or circumstances were recorded. Other invertebrates or finfish were identified to general type and enumerated. The CPUE data were calculated by converting all fishing times to a 24-hour standardized fishing period; T-tests were used for significance testing of catch rates for areas between years and for carapace widths by sex for areas between years.

RESULTS

Surveys to determine abundance and distribution of sea otters in the study area were conducted during July 1987, May 1988, and July 1989 (Table 2, Figures 3-8). Sea otters were abundant in the general vicinity of the Port Althorp and mouth of Idaho Inlet index sites for dungeness crabs, and they were observed just west of the Mud Bay site. In 1989, 10 sea otters were observed on the western fringe of the Gustavus Flat site; none were observed in the head of Idaho Inlet, although they were observed two-thirds of the way into the bay. The Beardslee Islands were not surveyed; however, they are away from otter concentrations, and National Park Service personnel who frequently visit the area have not observed them (G. Vequist, pers. commun.). Sea otters were first observed in Dundas Bay during 1989.

The total number of sea otters counted in the study area were relatively comparable during all 3 years (Table 2). Females with pups were observed almost exclusively in the Port Althorp area. The only significant range expansion noted during the 3 surveys was during 1989, when sea otters entered Dundas Bay, moved deeper into Idaho Inlet, and increased at Point Gustavus.

The CPUE (total crabs per pot) ranged from zero at Port Althorp during both 1988 and 1989 to 12.3 in the Beardslee Islands during

Table 2. Summary of sea otter surveys conducted in the Cross Sound-Icy Strait area during 1987, 1988 and 1989.

Count area	Date	Total otters	Pups	Survey quality
6001	11 July 1987	192	22	Good
6002	11 July 1987	75	9	Good
6003	9 July 1987	2	0	Good
6004	11 July 1987	1	0	Exc.
6005	11 July 1987	0	0	Good
6006	9 July 1987	7	0	Good
6007	8 July 1987	0	0	Poor
6008	8 July 1988	0	0	Poor
Subtotal		277	31	
6001	12 May 1988	166	26	Good
6002	11 May 1988	90	0	Good
6003	12 May 1988	17	3	Good
6004	13 May 1988	2	0	Good
6005	13 May 1988	3	0	Good
6006	13 May 1988	0	0	Good*
6007	13 May 1988	0	0	Fair
6008	11 May 1988	0	0	Good
Subtotal		278	29	
6001	18 July 1889	173	39	Good
6002	17 July 1989	26	0	Fair
6003	18 July 1989	6	0	Fair
6004	18 July 1989	0	0	Good
6005	19 July 1989	11	0	Good
6006	19 July 1989	36	0	Good
6007	19 July 1989	0	0	Good
6008	19 July 1989	0	0	Good
Subtotal		252	39	

* partially surveyed

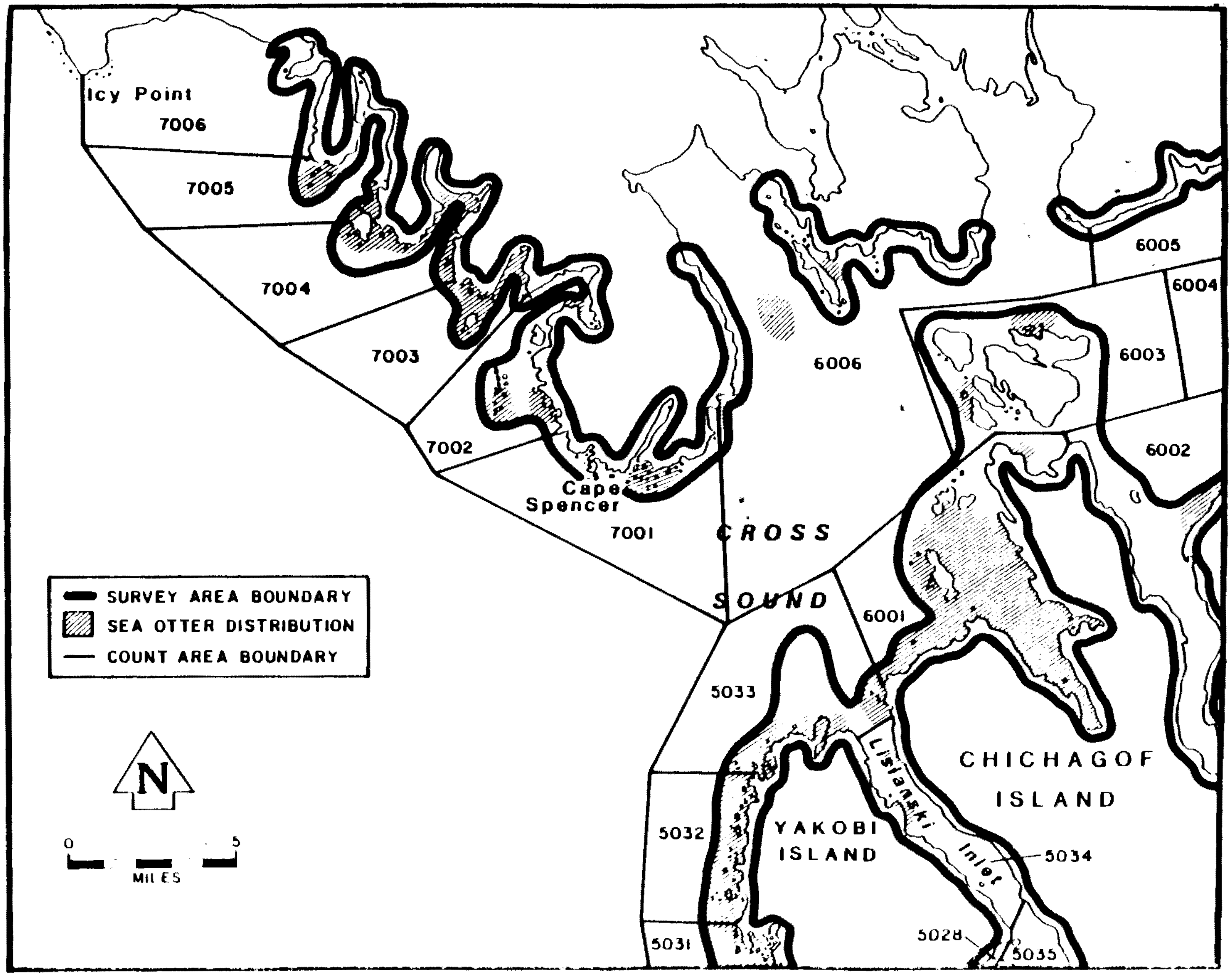

Figure 3. Area surveyed and sea otter distribution in the Cross Sound–Cape Spencer area during July 1987.

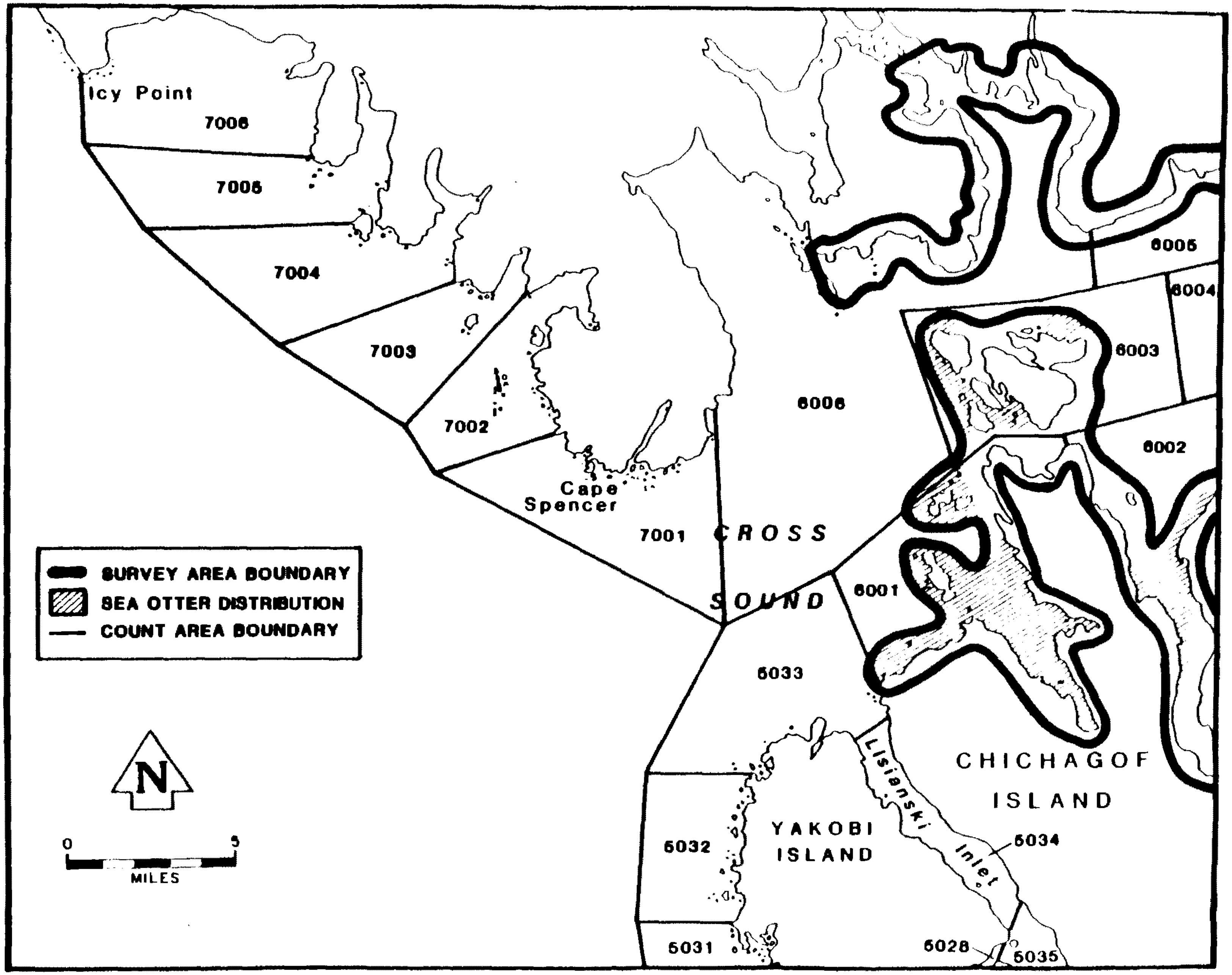

Figure 4. Area surveyed and sea otter distribution in the Cross Sound area during May 1988.

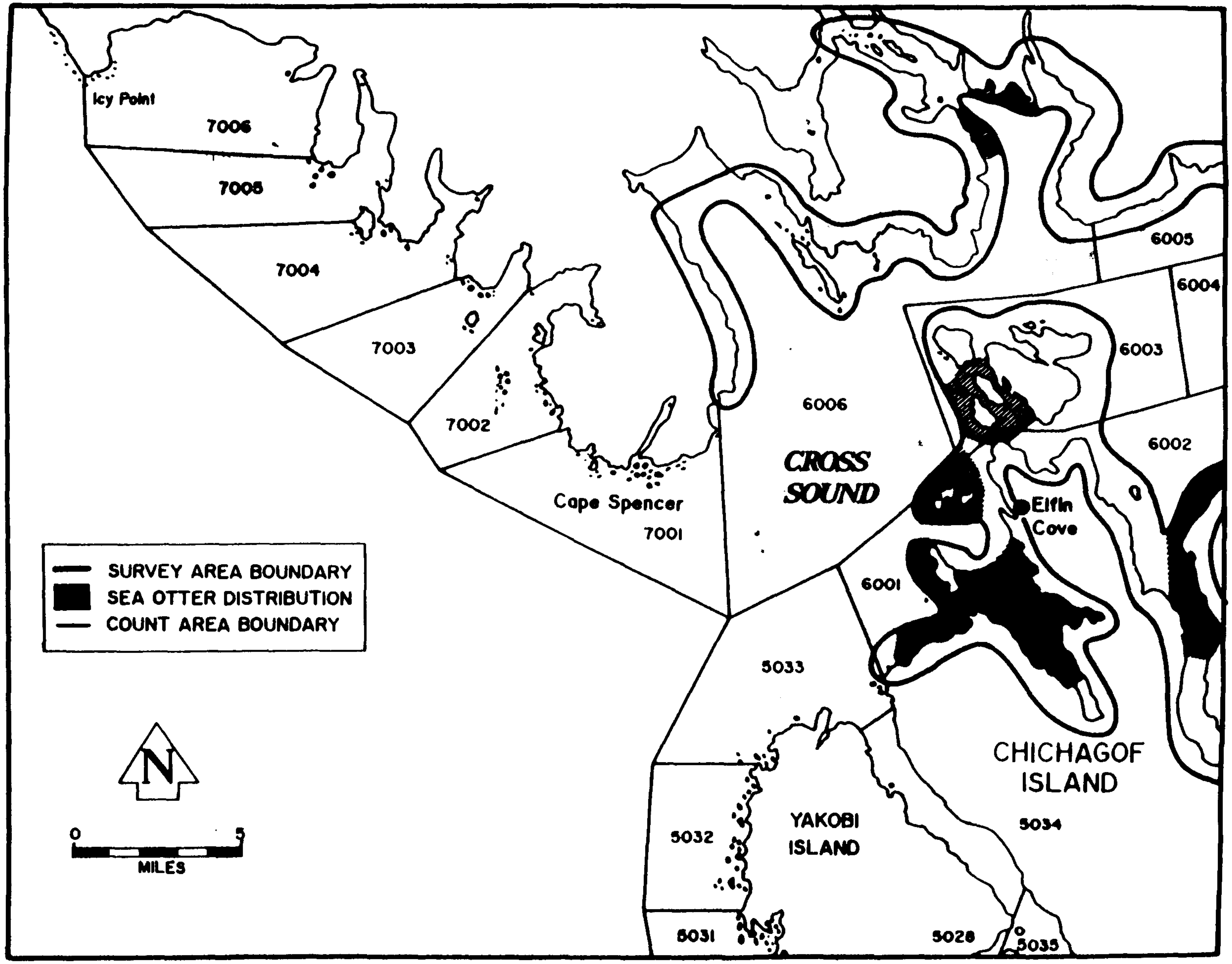

Figure 5. Area surveyed and sea otter distribution in the Cross Sound - Cape Spencer area during July 1989.

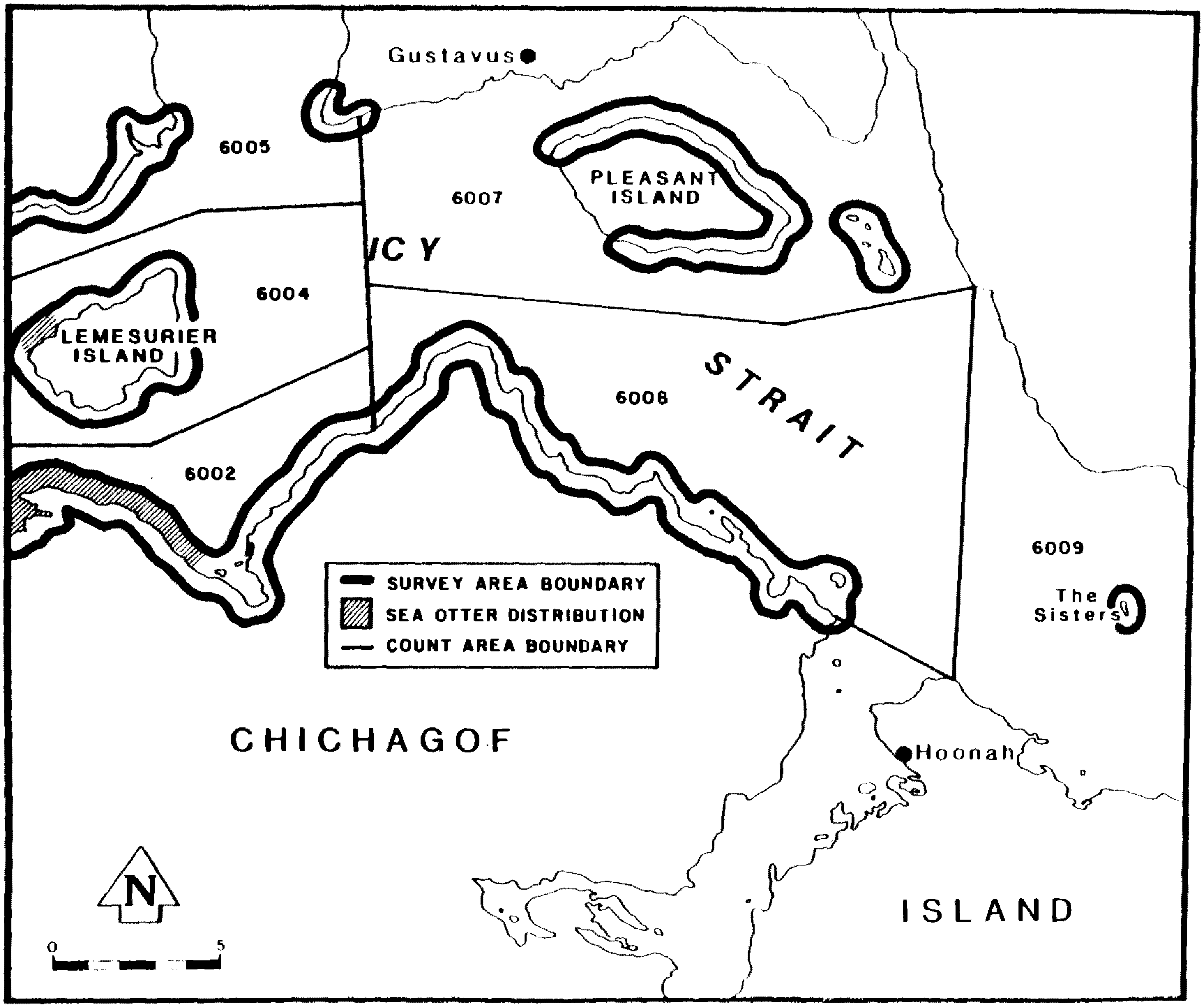

Figure 6. Area surveyed and sea otter distribution in the Icy Strait area during July 1987.

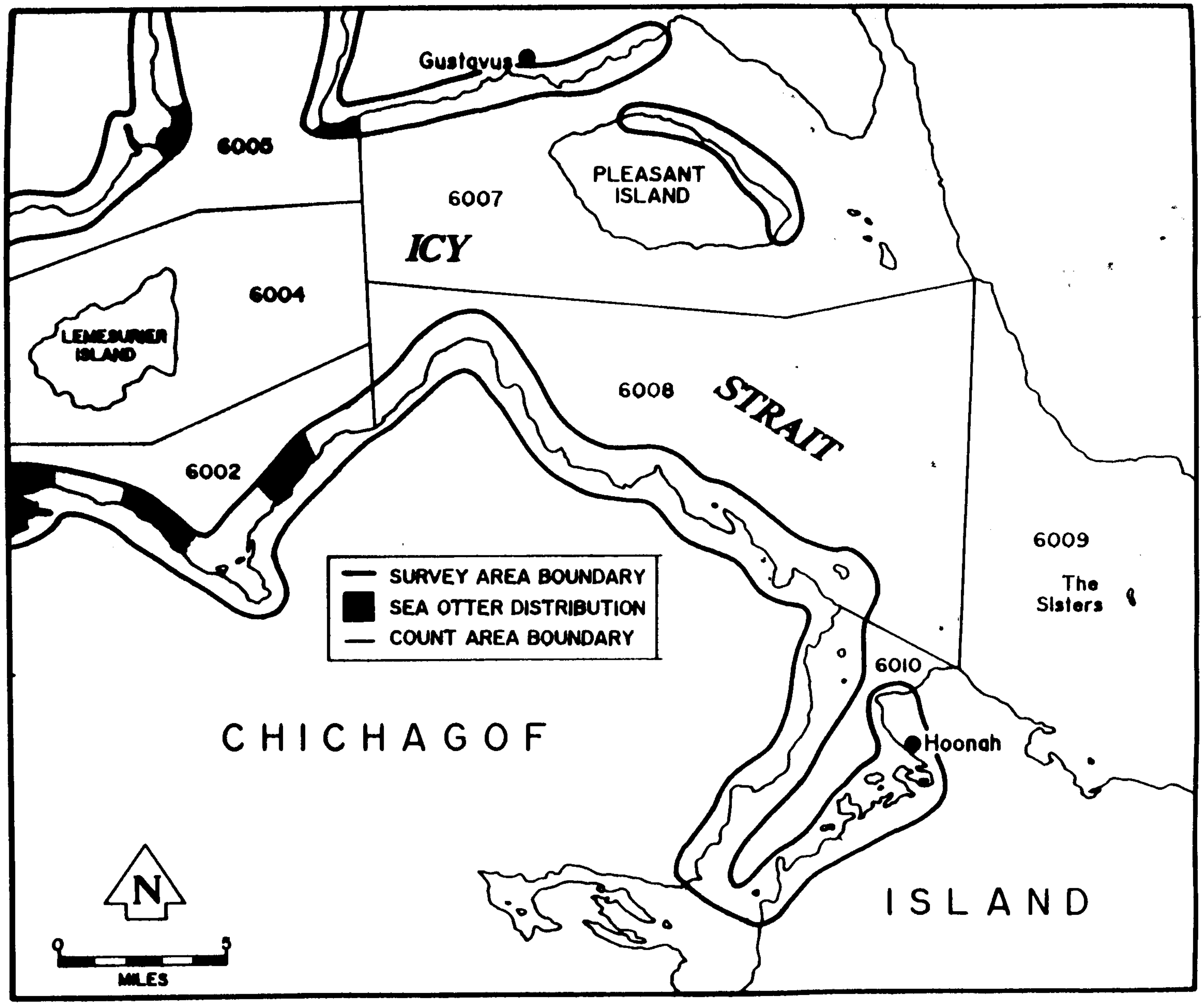

Figure 7. Area surveyed and sea otter distribution in the Icy Strait area during May 1988.

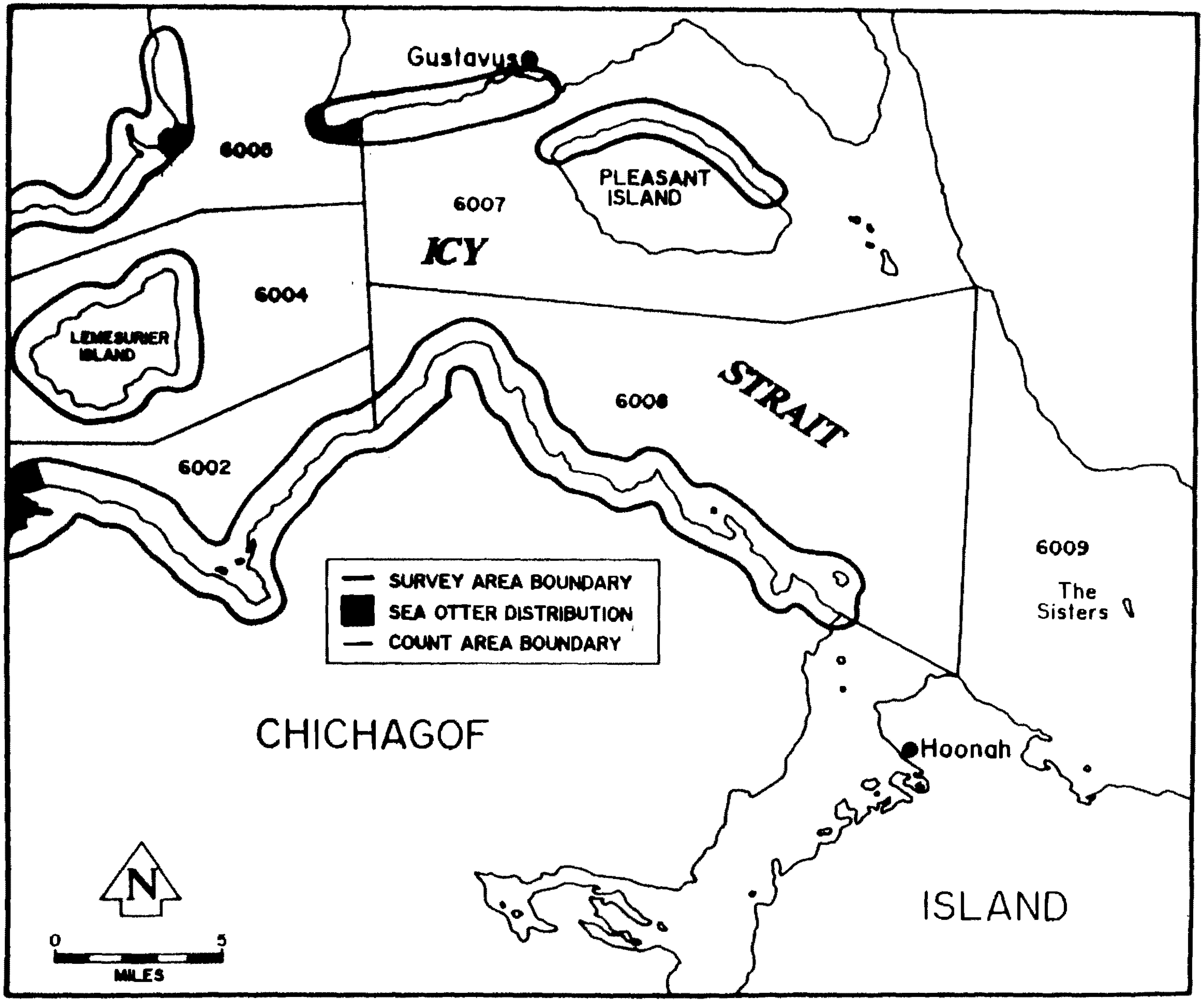

Figure 8. Area surveyed and sea otter distribution in the Icy Strait area during July 1989.

1988 (Table 3). For the total number of crabs, catch rates were similar for the northern sites (i.e., Gustavus Flat, Beardslee Islands, and Dundas Bay) as they were for the southern sites (i.e., Port Althorp, Idaho Inlet, and Mud Bay). At the 3 sites where surveys were conducted during both 1988 and 1989 (i.e., head Idaho Inlet, Mud Bay, and Beardslee Islands), significant (P = 0.0001) declines in total crab abundance were detected for the head of Idaho Inlet and the Beardslee Islands in 1989.

Table 3. Standardized catch per unit effort statistics (means and standard errors) for dungeness crab surveys in the Cross Sound-Icy Strait area during the summers of 1988 and 1989.

	Females		Legal males		Sublegal males		Total crabs	
Area	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Althorp (88)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Althorp (89)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. Idaho (88)	2.28	3.25	1.77	3.13	1.40	2.19	5.45	7.33
H. Idaho (89)	0.56	1.00	0.16	0.36	0.50	0.78	1.23	1.56
M. Idaho (88)	0.29	0.33	0.43	0.86	0.14	0.28	0.86	0.58
Mud Bay (88)	0.57	1.63	0.33	0.90	0.67	1.57	1.56	3.95
Mud Bay (89)	0.27	0.94	0.18	0.56	0.58	1.12	1.04	2.09
Gustavus (88)	4.60	3.97	3.49	3.58	1.18	1.52	9.27	6.28
Beards. (88)	7.08	4.76	3.44	2.61	1.76	1.72	12.28	6.72
Beards. (89)	3.59	4.74	0.99	1.38	0.76	1.60	5.33	6.22
Dundas (89)	2.96	4.94	2.69	3.38	4.84	7.37	10.49	11.75

A summary of carapace widths by sex is presented in Table 4. There was a general suggestion of reduced sizes for both sexes between 1988 and 1989; significant statistical differences were found in Mud Bay for females (P = 0.0002) and in the head of Idaho Inlet for males (P = 0.0003).

Table 4. Mean carapace widths in millimeters for dungeness crabs caught in the Cross Sound-Icy Strait surveys during 1988 and 1989.

Area	Male		Female	
	1988	1989	1988	1989
Idaho Inlet, mouth	180.9	--	150.0	--
Idaho Inlet, head	168.0	157.8	146.9	142.1
Mud Bay	160.4	154.0	141.8	130.6
Gustavus Flat	173.1	--	147.1	--
Beardslee Islands	170.7	168.6	149.3	150.2
Dundas Bay	--	161.2	--	142.3

DISCUSSION

Sea otters appeared to be slowly colonizing the Cross Sound-Icy Strait area. Even though an increase in abundance was not detected, the area occupied by sea otters increased. The Port Althorp area has been occupied since at least 1983 (Johnson et al. 1983), and sea otters appeared to be expanding their range to the north and east. Five of the 7 dungeness test-fishing index sites for crabs contained sea otters (i.e., Port Althorp, the mouth of Idaho Inlet, and Dundas Bay) or will likely be populated within the next several years (i.e., head of Idaho Inlet and Mud Bay); however, it will probably be awhile before substantial numbers of sea otters are found within the Gustavus Flat and Beardslee Islands sites, although ten were observed near Point Gustavus during the 1989 survey.

Based on our information so far, there is a tentative negative correlation between the abundance of crabs and the abundance and length of occupancy of sea otters in the general area of the index sites. No crabs were caught in the Port Althorp site, which has been occupied by substantial numbers of sea otters for at least 5 years. The CPUE was very low (0.86 crabs/pot) at the mouth of Idaho Inlet, where significant numbers of sea otters have been present for at least 1 year. Catch rates of crabs were highest at Dundas Bay, Gustavus Flat, and the Beardslee Islands, which have either not been colonized or only recently colonized. This type of comparison is not strictly justifiable because of the assumption that crab densities and therefore CPUEs would be similar for all sites without the presence of sea otters. This is probably not the case, because differences in habitat and/or fishing effort may account for different levels of crab abundance.

The declines in total crab catch rates between 1988 and 1989 at the head of Idaho Inlet and in the Beardslee Islands cannot be attributed to sea otters, because none were observed there during that period. These declines appeared to be part of a general stock depression that was reflected areawide by reduced catches in the commercial dungeness crab fishery. It was unlikely that fisheries were totally responsible for reduced abundance, because similar trends of lower catches were observed in sublegal male and female segments of the population (Table 3) that were not targeted nor retained by either the commercial or personal-use fisheries. The apparent, overall decline in dungeness crab abundance between 1988 and 1989 emphasizes the importance of monitoring the control sites. Dungeness crab abundance can be expected to fluctuate widely from causes not associated with sea otters, and in order to evaluate the impact of otter predation, data must be obtained on general trends in crab abundance.

We are uncertain of the biological significance of reduced sizes of female crabs in Mud Bay and male dungeness crabs at the head of Idaho Inlet between 1988 and 1989. However it is unlikely that it was caused by sea otter predation, because few were present at these sites.

The test of our hypothesis will require several years of monitoring the abundance of sea otters and crabs. The amount of time will depend on how rapidly sea otters populate the Mud Bay, head of Idaho Inlet, and Dundas Bay sites. We suspect that within the next 3 years substantial numbers of sea otters will have become established within these sites; then our hypothesis can be evaluated. The apparent large-scale regional decline in dungeness crab abundance may complicate interpretation of the impacts of the presence of sea otters. Additionally, evaluations on the impacts of sea otter predation on population structure of dungeness crabs should be possible through analyses of sex and size composition data collected during test fishing.

A power analysis of the current dungeness crab data set should be conducted in order to assess the probability of detecting changes in catch rates and sizes of crabs over time. The CPUE data by pot order (ADF&G files) indicated crabs were aggregated by location, sex, and size at most of the sampling sites, suggesting that variances can be lowered by stratification of sampling areas based on relative catch per pot information derived during the initial surveys. Strata boundaries can be additionally refined with data collected in future surveys. This will allow more statistically precise comparisons to be made at sampling sites over time and between sites.

Human harvest of dungeness crabs, which occurs at high levels at all sites excepting Port Althorp, is a possible confounding influence to our analysis of crab abundance in relation to the presence of sea otters. However we believe that all stocks are fully exploited, at least to the point of diminishing economic return; and since this is similar for all areas, it should not be a problem. In addition, only large males are harvested by humans, while sea otters are presumed to prey on sublegal males and females as well. Other predators also feed on dungeness crabs; however, none are thought to regulate populations, and the effects would likely be comparable in all areas.

ACKNOWLEDGMENTS

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