Decline in sea otter (*Enhydra lutris*) populations along the Alaska Peninsula, 1986–2001

Douglas M. Burn
Angela M. Doroff
Marine Mammals Management Office
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503
E-mail address (for D. M. Burn): douglas_burn@fws.gov

Abstract—During the 1990s, sea otter (*Enhydra lutris*) counts in the Aleutian archipelago decreased by 70% throughout the archipelago between 1992 and 2000. Recent aerial surveys in the Aleutians did not identify the eastward extent of the decline; therefore we conducted an aerial survey along the Alaska Peninsula for comparison with baseline information. Since 1986, abundance estimates in offshore habitat have declined by 27–49% and 93–94% in northern and southern Alaska Peninsula study areas, respectively. During this same time period, sea otter density has declined by 63% along the island coastlines within the south Alaska Peninsula study area. Between 1989 and 2001, sea otter density along the southern coastline of the Alaska Peninsula declined by 35% to the west of Castle Cape but density increased by 4% to the east, which may indicate an eastward extent of the decline. In all study areas, sea otters were primarily concentrated in bays and lagoon, whereas historically, large rafts of otters had been distributed offshore. The population declines observed along the Alaska Peninsula occurred at roughly the same time as declines in the Aleutian islands to the east and the Kodiak archipelago to the west. Since the mid-1980s, the sea otter population throughout southwest Alaska has declined overall by an estimated 56–68%, and the decline may be one of the most significant sea otter conservation issues in our time.

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During the 1990s, the sea otter (*Enhydra lutris*) population in the Aleutian archipelago declined at a rate of 17.5%/yr and, overall, counts decreased by 70% throughout the archipelago between 1992 and 2000 (Doroff et al., 2003). By modeling population trends back to the mid-1980s, Burn et al. (2003) estimated the population in the Aleutian Island chain decreased by 65,000 sea otters and was at about 10% of its carrying capacity in 2000. The 2000 aerial survey of Doroff et al. (2003) did not identify an eastward extent of the population decline however; therefore additional sea otter surveys along the Alaska Peninsula were needed.

Historic information on population status and trends is sparse for sea otters along the Alaska Peninsula. Sea otters were exploited to near extinction in the commercial fur trades (1742–1911) and were removed from large portions of their historic range worldwide (Kenyon, 1969; Lensink, 1962). At the time of their protection in 1911 by an international fur seal treaty, there were 13 remnant populations remaining worldwide, 11 of which persisted and grew to recolonize much of the former range of this species (Kenyon, 1969). Studies of both remnant native and translocated sea otter populations have indicated a pattern of colonization with high population growth rates up to 20% per year, and an expansion into adjacent, unoccupied habitat (Estes, 1990).

One remnant population survived on the north side of the Alaska Peninsula near Unimak Island (Kenyon, 1969; Schneider, 1976). Sea otter habitat in this area is unique in that shallow water (less than 100 m) extends up to 50 km offshore, covering more than 10,000 km of open water. The remnant population in this area likely numbered fewer than 100 sea otters in 1911 (Kenyon, 1969). This population grew steadily and expanded its range to the northeast along the Peninsula until 1970, when extreme sea ice conditions temporarily reduced the range and likely the size of the population (Schneider and Faro, 1975). By 1976, most of the sea otters in this area were concentrated between Cape Mordvinof and Cape Leontovich (Schneider, 1976).

In addition to the remnant population on the north side of Unimak Island, there were also two remnant populations of sea otters located to the south of the Alaska Peninsula in the Sandman Reefs and the outer Shumagin Islands (Kenyon, 1969). Sea otter habitat along the southern Alaska Peninsula differs from the northern side and comprises primarily rocky, mixed substrate, and extensive offshore reefs (Brueggeman et al.[1]). In the Sandman Reefs a small number of sea otters were sighted in

[1] Brueggeman, J. J., G. A. Green, R. A. Grotefendt, and D. G. Chapman. 1988. Aerial surveys of sea otters in the northwestern Gulf of Alaska and the southeastern Bering Sea. Minerals Management Service and NOAA final report, 87 p. Minerals Management Service, Anchorage, AK. [Contract no. 85-ABCV-00093.]

1922, and by 1962 the population had grown to an estimated 1625 sea otters (Lensink, 1962; Kenyon, 1969). Around the same time, the population in the Shumagin Islands was estimated to be 2724 sea otters (Kenyon, 1969).

The first systematic surveys of sea otter abundance along the north side of the Alaska Peninsula were conducted in the mid-1970s (Schneider, 1976), followed by surveys in 1982 and 1983 by Cimberg et al.[2] Brueggeman et al.[1] conducted quarterly surveys of both the northern and southern Peninsula in 1986 to assess sea otter abundance and seasonal distribution. The surveys conducted in 1986 provided seasonal estimates of abundance during a single, ice-free year, and a clear picture of habitat use in the mid-1980s along the Alaska Peninsula (Brueggeman et al.[1]).

The sea otter surveys described above were concentrated along the western end of the Alaska Peninsula where remnant populations existed and appeared to have recovered. By the late 1980s, sea otters had also returned to the nearshore waters of the entire peninsula as far east as Cape Douglas (DeGange et al.[3]). Prior to this survey in 1989, little was known about sea otter distribution and abundance on the Alaska Peninsula east of Kupreanof Point.

The objectives of our study were 1) to assess current sea otter distribution and abundance along the northern and southern Alaska Peninsula, 2) to contrast our results with prior surveys conducted in 1986 and 1989, and 3) to relate these data to the observed sea otter population declines observed elsewhere in southwest Alaska. We repeated the aerial survey methods developed by Brueggeman et al.[1] for sea otter habitat along the Alaska Peninsula which consisted of a combination of strip transects in offshore habitat (to the 70-m isobath) and coastline surveys (≤1 km of shore) of island groups within the study area. We also repeated the coastline surveys of DeGange et al.[2] to determine the eastward extent of the decline.

Materials and methods

Offshore survey areas

The north Alaska Peninsula (NAP) study area ranged from Cape Mordvinof on Unimak Island in the west to Cape Seniavin in the east. This area was further subdivided into two subunits (NAPa and NAPb), and a line at 162°W longitude divided the two subunits (Brueggeman et al.[1]). The south Alaska Peninsula (SAP) study area ranged from the Ikatan Peninsula in the west to the Shumagin Islands in the east. The seaward extent of both the NAP and SAP study areas was the approximate 70-m depth contour (Fig. 1A).

The strip transect method developed by Brueggeman et al.[1] consisted of a series of transects oriented north-south which were spaced every three minutes of longitude throughout the study area. In 1986, surveys were flown in a DeHavilland Twin Otter aircraft equipped with bubble windows at an altitude of 92 m and an airspeed of 185 km/h. Two observers, one on each side of the aircraft, relayed sea otter sighting information to a data recorder seated in the aft section of the aircraft. Sea otter sightings were grouped into three distance intervals spaced at right angles to the transect line: 0.0–0.23 km, 0.23–0.46 km, and 0.46–0.93 km. These distance zones were determined by using a clinometer to place marks on the inside of the bubble windows. Environmental information on sea state, visibility, and glare was recorded throughout the survey.

In May 2000 and April 2001, we repeated the survey conducted by Brueggeman et al.[1] using similar methods, with the exception that our survey aircraft was an Aero Commander equipped with bubble windows and we grouped sea otter sightings into five distance intervals: 0.0–0.115 km, 0.115–0.23 km, 0.23–0.345 km, 0.345–0.46 km, and 0.46–0.575 km.

Coastline survey areas

In 1986, Brueggeman et al.[1] also surveyed the coastlines of 22 islands on the south side of the Alaska Peninsula quarterly at a distance of 0.46 km from shore, using the same aircraft, altitude, and airspeed as in the offshore area surveys (Fig. 1B). In 1989, DeGange et al.[2] surveyed the coastlines of these same islands and the Alaska Peninsula from False Pass to Cape Douglas (Fig. 1C). The 1989 survey was conducted from Bell 206 and Hughes 500 helicopters at a distance of 0.2 km from shore at an altitude of 92 m and an airspeed of 130 km/h. We used similar methods (0.23 km from shore, altitude 92 m, airspeed 185 km/h) to survey the coastlines of these 22 islands and the Alaska Peninsula in April and May 2001. The area of the offshore surveys was adjacent to, but did not overlap, the area of the coastline surveys. Coastline surveys were not conducted in the NAP study area.

Offshore survey analyses

Prior to the analysis of the 2000-01 offshore survey data, we tested several assumptions made in the 1986 analysis regarding the detectability of sea otters as a function of 1) survey strip width, 2) survey conditions, and 3) time of day. We examined the distribution of sea otter sightings by distance zone using a chi-square analysis to determine the appropriate survey strip width to use

[2] Cimberg, R. L., D. P. Costa, and P. A. Fishman. 1984. Ecological characterization of shallow subtidal habitats in the north Aleutian Shelf. OCSEAP Final Rep. no. 4197, 99 p. U.S. Dept. of Commerce, National Oceanographic and Atmospheric Administration, Anchorage, Alaska 99501.

[3] DeGange, A. R., D. C. Douglas, D. H. Monson and C. M. Robbins. 1994. Surveys of sea otters in the Gulf of Alaska in response to the *Exxon Valdez* oil spill. Final report to the Exxon Valdez Oil Spill Trustee Council, Marine Mammal Study 6-7, 11 p. U.S. Fish and Wildlife Service, Anchorage, Alaska 99503.

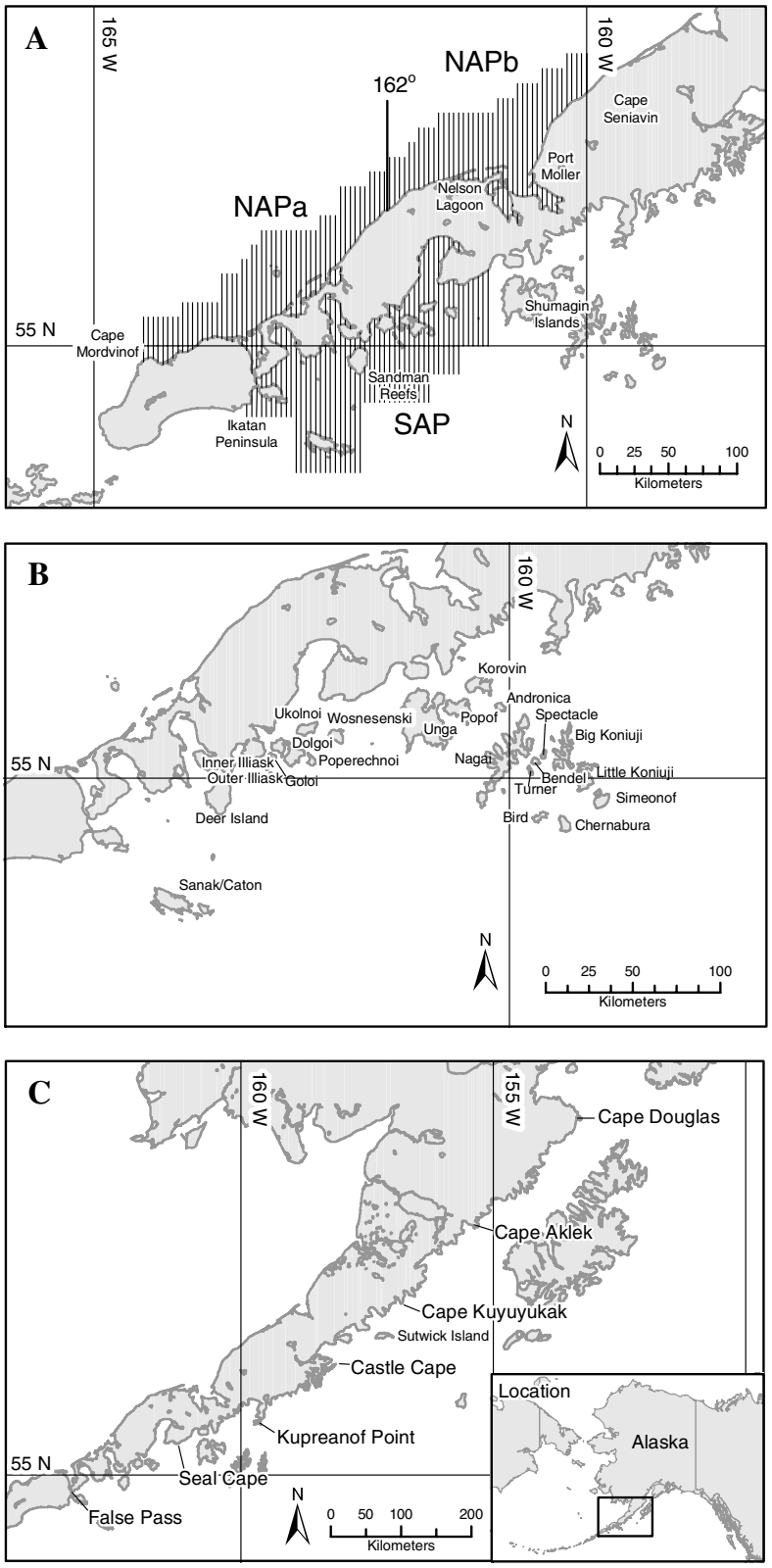

Figure 1

Sea otter (*Enhydra lutris*) survey areas along the Alaska Peninsula. (**A**) Offshore areas. (**B**) South Alaska Peninsula Islands. (**C**) Alaska Peninsula coastline. Surveyed areas in (B) and (C) include a 0.46-km zone adjacent to shore.

for estimating abundance. We calculated an encounter rate as the number of sea otter groups per km of survey effort and used this rate to examine the effects of time of day and environmental conditions (wave height, and visibility) on detectability of sea otters.

At the time of the surveys in 1986, researchers had documented a core resting period for sea otters which occurs about mid-day (Garshelis and Garshelis, 1984; Estes, 1977). As a result, Brueggeman et al.[1] subset the 1986 data using only effort and observations recorded between 0830 and 1430 hours local sun time for their abundance estimates. Recent studies indicate activity patterns for sea otters are strongly linked to sex, age, weather condition, season, and time of day (Gelatt et al., 2002). We tested the assumption that sea otters were more visible during the core resting period using a *t*-test of the encounter rate for each transect during presumed rest and nonrest periods for the 1986 and the 2000–01 data.

We measured the area of the NAP and SAP study areas using a geographic information system (Arc/Info). Our measurements differed from those of Brueggeman et al.,[1] presumably because the original researchers had not used an equal-area map projection in their calculations. Like Brueggeman et al.,[1] we estimated abundance of sea otters in the Alaska Peninsula offshore areas using the modified ratio of means estimator (method I) of Estes and Gilbert (1978). Noting computational errors in the original analysis, we recalculated abundance estimates from the original 1986 data of Brueggeman et al.[1] The proportion of sea otters within the survey swath that went undetected by observers was not estimated in either our survey or the surveys of Brueggeman et al.[1]; therefore all abundance estimates were biased low to an unknown degree. We computed the proportional change in abundance between survey periods ($(N_{t2}–N_{t1})/N_{t1}$) as a range, using the minimum and maximum estimates from 1986 as a baseline and assuming no significant difference in the proportion of sea otters detected between surveys.

Coastline survey analyses

We calculated the area surveyed as the product of the coastline length and the survey strip width and calculated the density of sea otters per km^2 surveyed. Once

again assuming no significant difference in the proportion of sea otters detected between surveys, we computed the proportional change in density between survey periods ($(D_{t2}-D_{t1})/D_{t1}$) of sea otter density at each island within the study area between 2001 and 1986 (Brueggeman et al.[1]) and each Alaska Peninsula coastline segment between 2001 and 1989 (DeGange et al.[2]).

Results

Offshore surveys

In 1986, Brueggeman et al.[1] flew four surveys and an average of 3676 km of transect effort per survey. The majority (59%) of the 1986 survey effort was conducted in Beaufort sea state 2 (wind less than 7.4–11.1 km/h, no whitecaps) or less; and 95% of the survey effort was conducted with visibility categorized as good or better. In May 2000 and April 2001, we flew 6334 km of transects and 56% of our effort was conducted in Beaufort sea state 2 or less; 97% of our effort was conducted in visibility categorized as good or better.

In 1986, sea otter detection probability was not uniform between sighting zones (χ^2=1796, df=2, P<0.0001) and substantially more sea otters were observed than expected in the 0.0–0.23 km distance zone (Fig. 2A). As a result, Brueggeman et al. (1988) used only this zone in their calculation of sea otter abundance. In our 2000–01 surveys, sea otter detection probability was also not uniform (χ^2=217, df=5, P<0.0001). The observed frequency of sea otter sightings exceeded the expected value in our second (0.115–0.230 km) and third zones (0.230–0.345 km) but in the first zone (0.0–0.115 km) we recorded only half as many sea otter sightings as in the second zone (Fig. 2B). Therefore, only sightings from the second and third zones were used in our calculation of sea otter abundance. As a result, the overall width of the survey strip was the same for the 1986 and the 2000–01 surveys (0.46 km), but our strip was offset by 0.115 km from the trackline. The proportion of all sea otter sightings was similar between the usable zones in 1986 (62.8%) and 2000–01 (62.4%).

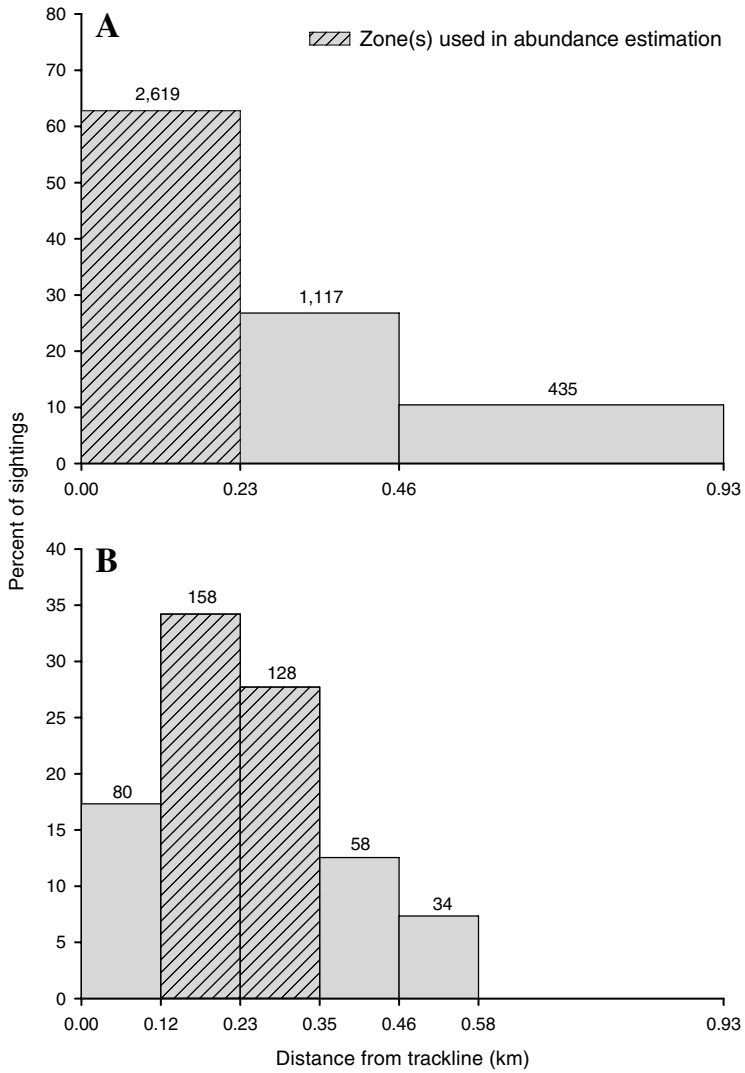

Figure 2

Distribution of sea otter (*Enhydra lutris*) sightings in offshore areas grouped according to perpendicular distance from the survey trackline. (**A**) 1986 data from Brueggeman et al.[1] (**B**) 2000–01 data from this study. Values above bars represent total number of sightings in each zone.

Sea otter encounter rate (otter groups/km) decreased as wave height increased and visibility conditions became worse in both the 1986 and 2000–01 surveys. As noted by Kenyon (1969), wave height has a profound influence on the ability of observers to detect sea otters. Prior to calculating abundance estimates for both 1986 and 2001, we subset both data sets to include only those transects where Beaufort sea state was ≤2 and visibility was categorized as good or excellent for counting sea otters. This procedure reduced the 1986 usable survey effort by 42%, and the 2000–01 survey efforts by 44%.

Sea otter encounter rates did not differ significantly between rest and nonrest periods in the 1986 data (t=1.63, df=79, P<0.1064). Likewise, there was no difference in encounter rates for rest and nonrest periods in 2000–01 (t=–0.79, df=71.6, P<0.4327). As a result, we did not exclude any survey effort and sea otter sightings based on time of day.

Table 1

Sea otter (*Enhydra lutris*) population estimates for Alaska Peninsula offshore study areas. Study areas: north Alaska Peninsula a [NAPa] = 6257 km^2; and b [NAPb] = 5531 km^2; south Alaska Peninsula [SAP] = 9469 km^2.

Survey area	Survey date	Total number of transects	Area sampled (km^2)	Number of otter groups	Density (groups/ km^2)	Group abundance	Mean group size	Estimated abundance	95% confidence interval
NAPa	March 1986	35	446.2	243	0.545	3408	2.082	7096	±2558
	Late June–early July 1986	39	398.8	124	0.311	1945	2.177	4236	±1818
	August 1986	31	421.7	225	0.534	3338	2.169	7240	±2978
	October 1986	36	511.6	274	0.536	3351	1.982	6642	±2050
	May 2000	40	552.3	18	0.033	204	1.833	374	±318
NAPb	Late June–early July 1986	29	469.5	98	0.209	1155	1.939	2238	±840
	August 1986	6	120.4	23	0.191	1056	1.870	1975	±2212
	October 1986	14	314.3	42	0.134	739	1.214	897	±467
	May 2000	40	443.3	184	0.415	2296	1.897	4354	±3007
SAP	March 1986	26	358.3	254	0.709	6712	2.071	13,900	±6456
	Late June–early July 1986	33	424.8	227	0.534	5060	2.775	14,042	±5178
	October 1986	33	442.6	418	0.944	8943	1.957	17,500	±5768
	April 2001	38	631.2	22	0.035	330	3.045	1005	±1597

The estimated abundance of sea otters decreased by 91–94% in the NAPa study area, which ranged from 4236–7240 in 1986 to 374 in 2000 (Table 1). Estimated abundance increased by 95–385% in the NAPb study area, which ranged from 897 to 2238 in 1986 to 4354 in 2001. Overall, abundance estimates in the NAP study area declined by 27–49% between 1986 and 2000. Within the NAP area, sea otters were distributed primarily near the coast rather than further offshore as was observed in 1986 (Fig. 3). In May 2000, the majority of sightings occurred in the Port Moller and Nelson Lagoon areas, which had contained few otters during the 1986 surveys. Estimated abundance within the SAP study area declined by 93–94%, from 13,900–17,500 in 1986 to 1005 in 2001. Similar to the NAP results, areas that had previously supported dense aggregations of sea otters were largely vacant in 2001 and the areas of highest concentrations were in bays and lagoons.

Coastline survey analyses

Between 1986 and 1989 there was considerable variability in sea otter counts at islands in the south Alaska Peninsula study area (Table 2). Some areas had increased (Sanak, Caton, and the Pavlof Islands) while others decreased (Deer Island, Shumagin Islands). However by 2001, sea otter counts and density had decreased at nearly all islands and net losses of over 100 otters occurred at Deer, Dolgoi, Goloi, Unga, and Nagai islands. Overall, sea otter counts at these islands declined from 2174 in 1986 to 402 in 2001—a 63% decline in density.

In April and May 2001 we surveyed approximately 3800 km of coastline from Cape Douglas to False Pass (Table 3). Sea otter density in 2001 was 35% lower than in 1989 for the three westernmost coastline segments from False Pass to Castle Cape (1782 km of coastline). To the east of Castle Cape, sea otter density was 4% greater in 2001 than in 1989 (2018 km of coastline). These results indicate that an eastward extent of the decline along the Alaska Peninsula may occur in the area of Castle Cape. Overall, sea otter density declined by 12.4% along the coastline of the Alaska Peninsula from False Pass to Cape Douglas between 1989 and 2001.

Discussion

When compared to surveys conducted in 1986, our results indicated that sea otter abundance has declined severely in the SAP and NAPa study areas along the Alaska Peninsula, whereas sea otter abundance increased in the NAPb study area (specifically Port Moller) and east of Castle Cape along the south side of the Peninsula. To determine the geographic extent and magnitude of the sea otter population decline, current data were needed to assess population abundance and trends along the Alaska Peninsula.

Variations in survey methods limited our ability to assess population trends for the Alaska Peninsula prior to 1986. In 1976, the sea otter population along the NAP was estimated to be 17,000 and continued range expansion was expected (Schneider, 1976). In 1982–83, seasonal estimates of sea otter abundance in the NAP study area varied between March (1454), August (10,325), and October (1880) which led Cimberg et al.[2] to speculate that there was a large-scale seasonal migration of sea otters between the Bering Sea and North Pacific Ocean. Sea otter distribution and abundance

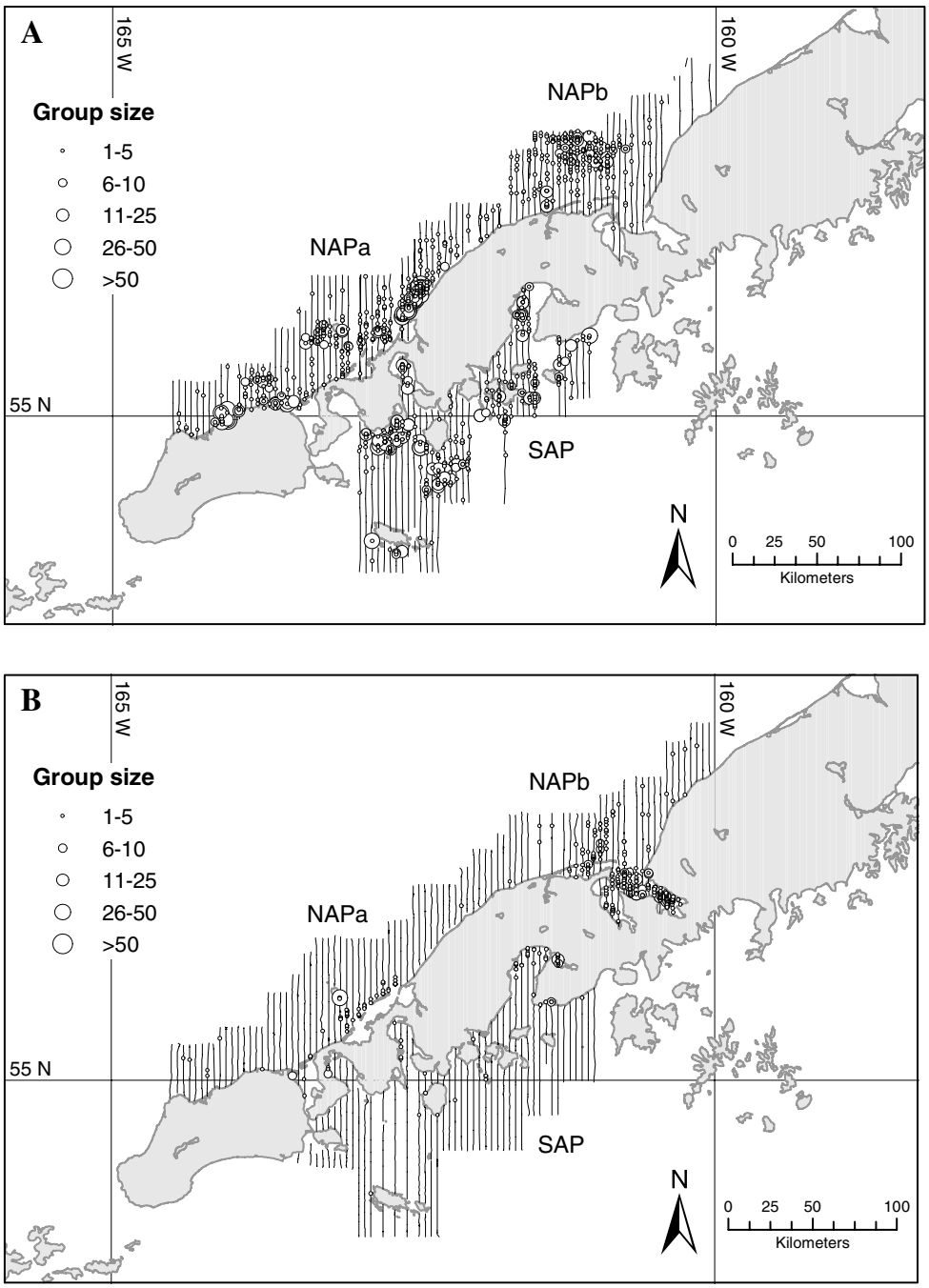

Figure 3

All survey transects and sea otter (*Enhydra lutris*) sightings in offshore areas. (**A**) Late June–early July 1986. (**B**) May 2000 (north Alaska Peninsula [NAP], a and b), April 2001 (south Alaska Peninsula [SAP]).

remained relatively constant over the spring, summer, and fall seasons for both the NAP and SAP study areas in 1986 which led Brueggeman et al.[1] to conclude that there was no indication that sea otters were redistributed from the northern to the southern Peninsula during the winter months. Instead, Brueggeman et al.[1] attributed the differences in the survey results between 1982–83 and 1986 to the viewing conditions and wind speed in which Cimberg et al.[2] conducted their March and October surveys. Although both the 1976 and 1983 estimates were adjusted for sea otters missed by observers, the 1986 estimates were not. Evans et al.[4]

Table 2

Alaska Peninsula island coastline lengths, sea otter (*Enhydra lutris*) counts, sea otter densities, and estimated population change. Survey strip width for the 1986 survey was 0.92 km, for 1989 it was 0.4 km, and for 2001 it was 0.46 km.

Island name	Coastline length (km)	Sea otters counted			Sea otter density (otters/km^2)			% change in density 1989–2001
		1986	1989	2001	1986	1989	2001	
Sanak and Caton	178	13	168	12	0.08	2.36	0.15	+84.6
Deer Island	61	245	71	19	4.35	2.90	0.67	–84.5
Dolgoi	94	185	93	15	2.14	2.47	0.35	–83.8
Goloi	14	113	62	1	8.77	11.07	0.16	–98.2
Inner Illiask	13	77	68	9	6.44	13.07	1.51	–76.6
Outer Illiask	17	82	305	4	5.24	44.85	0.51	–90.2
Wosnesenski	32	29	28	3	0.99	2.19	0.20	–79.3
Ukolnoi	38	54	133	21	1.54	8.75	1.20	–22.2
Poperechnoi	22	80	26	1	3.96	2.95	0.10	–97.5
Unga	231	568	275	182	2.67	2.98	1.71	–35.9
Popof	72	72	73	4	1.09	2.53	0.12	–88.9
Korovin	65	101	47	9	1.69	1.81	0.30	–82.2
Andronica	22	31	15	0	1.53	1.70	0.00	–100.0
Nagai	342	184	141	52	0.58	1.03	0.33	–43.5
Big Koniuji	160	52	18	33	0.35	0.28	0.45	+26.9
Turner and the Twins	16	6	9	0	0.41	1.41	0.00	–100.0
Bendel	17	35	7	2	2.24	1.03	0.26	–88.6
Spectacle	15	17	12	7	1.23	2.00	1.01	–17.6
Little Koniuji	95	65	20	0	0.74	0.53	0.00	–100.0
Simeonof	49	65	5	24	1.44	0.26	1.06	–26.2
Chernabura	30	20	2	0	0.72	0.17	0.00	–100.0
Bird	31	80	11	4	2.81	0.89	0.28	–90.0
Total	1614	2174	1589	402	1.46	2.46	0.54	–63.0

Table 3

Alaska Peninsula coastline segment lengths, sea otter (*Enhydra lutris*) counts, sea otter densities, and estimated population change. Survey strip width for the 1989 survey was 0.4 km; for 2001 it was 0.46 km.

Coastline segment 1989–2001	Coastline length (km)	Sea otters counted		Sea otter density (otters/km^2)		% change in density
		1989	2001	1989	2001	
False Pass to Seal Cape	715	622	461	2.17	1.40	–35.6
Seal Cape to Kupreanof Point	370	196	50	1.32	0.29	–77.8
Kupreanof Point to Castle Cape	697	48	25	0.17	0.08	–54.7
Castle Cape to Cape Kuyuyukak	639	1007	1193	3.94	4.06	+3.0
Cape Kuyuyukak to Cape Aklek	495	177	352	0.89	1.55	+72.9
Cape Aklek to Cape Douglas	814	570	497	1.75	1.33	–24.2
Sutwick Island	70	12	73	0.43	2.27	+429.0
Total	3800	2632	2651	1.73	1.52	–12.4

estimated that observers flying in a Twin Otter aircraft recorded 42% of the sea otters present within the area surveyed. Adjusting the 1986 results by this amount yields a range of 10,086–17,238; therefore the population may not have changed substantially between 1976 and 1986. By 2000 however, it is clear that sea otters had declined within the NAP study area, and although the data history for the SAP study area is even more sparse, there is little doubt that the population in this area has also declined severely since 1986.

The distribution of sea otters along the north side of the Alaska Peninsula is rather unique. Because of the broad shelf, large rafts of otters have been observed at distances of 50 km or more from shore. The area is also subject to seasonal sea ice that can have a profound impact on sea otter distribution, and in extreme ice years, result in significant mortality (Schneider and Faro, 1975). It is unclear if behavior and movement patterns in the NAP area are different from other areas in the north Pacific. In the 1960s and 1970s it was thought that sea otters along the northern Alaska Peninsula spent much, if not all, of their life in offshore waters (Kenyon, 1969; Lensink, 1962; Schneider, 1976). Cimberg et al.[2] suggested that sea otters may migrate through False Pass from the Bering Sea to the north Pacific Ocean during the winter months to avoid being trapped by shore-fast sea ice. Of the two study areas along the north side of the Alaska Peninsula, the NAPa study area located farther south and west is more likely to remain ice-free, and therefore may be important for the overall survival of sea otters in this area (Schneider and Faro, 1975). If sea otters remain concentrated throughout the year in Port Moller, which is in the NAPb study area, they may be vulnerable to mortality by extensive sea ice events in the future.

Information derived from sea ice data with spatial and temporal resolution suitable for evaluating the impacts of extensive sea ice on sea otters is not readily available. Detailed sea ice data for the NAP study area from the National Ice Center is only available for the period from 1997 to the present. In March 1999 shore-fast ice was present in both Port Moller and Izembek Lagoon, and nearshore areas were almost totally covered by sea ice. Similar conditions also occurred in January 2000. In both instances, sea otter mortality was reported by residents of Port Heiden, Alaska, located to the northeast of the NAP study area (Esslinger[5]; Snyder[6]). Human habitation in the NAP study area is extremely sparse in winter, which may explain why there were no reports of sea otter mortality in this area. Given the degree of sea ice present, it is possible that the extreme ice conditions in 1999 and 2000 may have resulted in the death of some sea otters within our study area. The geographic pattern of the decline does not exactly fit what would be expected from sea ice however, because the decline occurred in the NAPa study area, which is presumed to be less vulnerable to these events. Although it is possible that extreme sea ice conditions may have been a contributing factor, it was likely not the sole cause of the decline in the NAP study area.

In our surveys of the NAP study area, sea otter abundance declined severely in NAPa but had increased in NAPb. It is unclear to what degree otters may move between these respective study areas. Quarterly surveys in 1986 did not indicate seasonal changes in distribution between the NAPa and NAPb portions of the study area. Monnett et al.[7] used radio telemetry to study sea otter movements in the NAPa study area from 1986 through 1988 and found that study animals did not move between NAPa and NAPb or to the SAP study area as previously hypothesized by Cimberg et al.[2] The average distance between extreme locations was only 18.4 km; however, the sample size of sea otters in the Monnett et al.[7] study was small (n=14). The large concentration of sea otters observed in Port Moller and Nelson Lagoon in May 2000 may be a seasonal event; large numbers of sea otters are typically observed in that area in May, but disperse by June (Murphy[8]). Compared to the ecology of other areas, the ecology of sea otters along the north side of the Alaska Peninsula is poorly understood and additional study is warranted.

In addition to changes in abundance there were also changes in sea otter distribution in the 2000–01 surveys. In 1986, sea otters were observed up to 50 km from shore during all surveys. In the 1970s and 1980s, large rafts of up to 1000 sea otters were distributed well offshore (Kenyon, 1969; Schneider, 1976; Brueggeman et al.[1]). By 2001 sea otters were, with rare exception, located in bays and lagoons along the Peninsula rather than in the offshore habitat in both the NAP and SAP study areas. Estes et al. (1998) hypothesized that declines in sea otters in the Aleutian islands during the 1990s may have been caused by increased predation by killer whales (*Orcinus orca*). One line of evidence that led to this conclusion was a lower sea otter mortality in the sheltered area of Clam Lagoon than in the exposed area of Kuluk Bay on Adak Island. The observed distribution of sea otters within bays and lagoons along the Alaska Peninsula in 2000–01 is not inconsistent with the predation hypothesis of Estes et al. (1998). Alternatively, nearshore waters may constitute preferred

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[5] George Esslinger. 1999. Personal commun. U.S. Geological Survey, Alaska Science Center. 1011 East Tudor Road, Anchorage, AK 99503-6103.

[6] Jonathan Snyder. 2000. Personal commun. U.S. Fish and Wildl. Serv., Mar. Mamm. Manage. Office, 1011 East Tudor Road, Anchorage, AK 99503-6103.

[7] Monnett, C., L. M. Rotterman, D. B. Sniff, and J. Sarvis. 1988. Movement patterns of western Alaska Peninsula sea otters. Minerals Management Service, OCSEAP (Offshore Continental Shelf Engineering Assessment Program) Research Unit 688, 51 p.

[8] Murphy, B. 2002. Personal commun. Alaska Department of Fish and Game, Division of Commercial Fisheries, 211 Mission Road, Kodiak, AK 99615-6399.

habitat for sea otters, and at low densities it is possible that these may be the only areas where they occur.

We are reasonably confident that the 2000–01 surveys yielded results that were comparable to baseline surveys because the methods were closely repeated. The difference in distribution of sea otter sighting zones may have been a result of different aircraft configurations. Although both aircraft were equipped with bubble windows, the size and shape of these windows were probably not identical. We accounted for any differences by selecting the zones best suited to estimate sea otter abundance for each survey period. In our data analysis, we also accounted for the effects of survey conditions (Beaufort sea state and viewing condition) in both data sets. Our results indicate that in addition to changes in sea otter abundance, distribution had changed markedly between study periods as well. Because sea otter distribution is currently concentrated closer to the coast, we recommend revising the survey design for future population surveys in this area. Rather than considering the offshore area as a single survey stratum, it would be more efficient to define nearshore and offshore survey strata and allocate survey effort accordingly.

To the west of the Alaska Peninsula study areas, the sea otter population in the Aleutian archipelago has declined to less than 10% of the estimated carrying capacity (Burn et al., 2003). Further westward in the Commander Islands, Russia, the sea otter population appears to have remained stable over the same time period (Burkanov and Burdin[9]). To the east of the Alaska Peninsula, sea otters have declined by an estimated 56% in the nearby Kodiak archipelago since 1989 (Doroff et al.[10]), but they appear to have remained relatively stable in the areas of Cook Inlet and Kenai Fiords (Bodkin et al.[11]) According to the most recent population surveys, the geographic extent of the sea otter decline does not appear to have exceeded the range of the southwest Alaska population stock as described by Gorbics and Bodkin (2001), where the overall decline has been estimated at 56–68%. Because the cause of the decline remains unknown, areas at the periphery of the current decline should be regularly monitored in the future. Given the close proximity between the Aleutian Islands and the Commander Islands, Russia, future research there may improve our understanding of the cause of the decline in southwest Alaska.

The sea otter decline, which has occurred over a broad geographic area, encompasses different habitat types in southwest Alaska. The Aleutian Island chain is primarily volcanic in origin and the majority of habitat for foraging (waters <40 m) is concentrated relatively near shore and is primarily a rocky substrate. The Alaska Peninsula includes extensive soft-sediment offshore habitat available to sea otters. Despite these differences, the declines in sea otter populations are similar between the Alaska Peninsula and the Aleutian archipelago in both severity and time period, which may imply a common cause. In addition to sea otters, severe declines of harbor seals (*Phoca vitulina*), Steller sea lions (*Eumetopias jubatus*), and fur seals (*Callorhinus ursinus*) have also been documented within the same general region, which suggests broader ecosystem-level changes may be involved. Our survey results, along with evidence of a declining sea otter population in the Kodiak archipelago, prompted the U.S. Fish and Wildlife Service to propose listing sea otters in southwest Alaska as threatened under the U.S. Endangered Species Act. The population decline in southwest Alaska is one of the most significant conservation issues for the sea otters in our time.

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