A REVIEW OF CALIFORNIA SEA OTTER, ENHYDRA LUTRIS, SURVEYS

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ABSTRACT

Recent surveys (1977 to 1983) of the sea otter, Enhydra lutris, in California were summarized and compared to past surveys, to evaluate the adequacy of current survey design and to make inferences about current population status.

Ground counts within selected index areas provided the best indicator of population trends. These data suggest a rather remarkable stability in the long-term occupied range. Range-wide aerial surveys with ground truth stations provided the best available data for estimating total population size. The most recent (1979) survey yielded a population estimate of approximately 1500 sea otters. Comparisons with past surveys suggest there have been no demonstrable changes in population size since at least 1976.

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INTRODUCTION

Prior to the fur trade era (1780 to 1900) sea otters, Enhydra lutris, ranged from Morro Hermoso, Baja California, northward and westward through the Aleutian and Commander Islands to the western rim of the North Pacific Ocean (Kenyon 1969). Major changes in the abundance and distribution of sea otters have been associated with their decimation during the fur trade era. Subsequently, with federal and state protection, remnant groups have reoccupied increasingly large portions of their former range.

The existence of a small remnant population of sea otters in California became common knowledge in 1938 with the report of a group of approximately 50 animals just north of Point Sur (Bolin 1938). Published reports and Fish and Game warden records suggest there may have been as many as 300 sea otters in 1938.

During the next decade counts were made by the California Department of Fish and Game (CDFG) at periodic intervals. On the basis of these counts, the total population was thought to be about 500 sea otters. The first systematic survey was conducted in 1957 (Boolootian 1961) yielding a count of 638 sea otters.

Subsequent changes in the abundance and distribution of this population were monitored utilizing a variety of survey techniques. A brief review of published material on range-wide surveys conducted in California is presented in the discussion section to provide a background perspective with which to evaluate current survey results.

The changes in abundance and distribution of the remnant sea otter population off California have been monitored with interest for a variety of reasons. Concern for the welfare of this remnant population and for the loss of shellfish fisheries attributable to sea otter foraging have led to increased research efforts on the size and status of the population.

California Department of Fish and Game studies on the size and status of the California sea otter population have utilized either rangewide surveys or surveys of selected index areas to estimate or detect trends in geographical distribution and total population size. This report reviews survey results prior to 1977 and summarizes the results of recent survey efforts (1977 to 1983) to evaluate the adequacy of current survey designs and make inferences about current population status.

MATERIALS AND METHODS

Sea otter population studies in California have utilized a variety of aerial and ground survey techniques. A brief summary of major changes in these techniques and the results of surveys prior to 1977 are presented in the discussion section. Major changes were also implemented in techniques used in recent (1977-1983) rangewide surveys.

Techniques used during ground surveys, whether part of a rangewide survey or restricted to surveys of selected areas, however, have remained relatively unchanged. Recent surveys were conducted by two-person teams scanning with binoculars and a 89mm field model Questar telescope. The vantage point and boundaries for each continguous count area were selected to optimize viewing conditions and minimize double counting or missing moving animals. The location of individuals and groups were marked on survey maps (Figure 1). Other pertinent information including activity, tag identification when present, food items being consumed and relative age of the otters was also noted. Field identification of age was restricted to designating otters as independent, large pup or small pup. Pups were identified as small if natal or wooley pelage was observed.

Aerial survey patterns were determined by field conditions. Typically, two or three parallel passes were made over a count area. Along rocky coastline, count areas rarely exceeded 3.2 km in length and were delineated using clearly identified boundaries. Along sandy coastline the length of a count area and the number of passes were increased to insure adequate coverage and increase efficiency. The location of individuals and groups was recorded on maps comparable to those used for ground based surveys.

Both ground based and aerial surveys were usually conducted between 0900 and 1400 hours on days when viewing conditions were judged to be adequate. Conducting counts only during this period helped control the influence that changes in sea otter activity and viewing conditions have on the precision and accuracy of a count.

Rangewide surveys, designed to estimate population size or trends, have relied on varying combinations of ground based and aerial observations. The first rangewide survey performed during this report period was patterned after a 1976 CDFG survey (Geibel and Miller 1984). The population estimate was derived from an expansion of a rangewide aerial count based on a comparison of ground and aerial counts obtained within ground "truth" stations. The term "truth" implies a level of accuracy which, in reality, may not be achieved. However, ground counts within "truth" stations provide the most accurate count available because the count area is small and close. Further, the observer occupies the station for a relatively long time.

Estimates were made, using these comparisons, for three separate segments (survey days) and summed for a total population estimate.

In 1982 the CDFG and the U.S. Fish and Wildlife Service (USFWS) conducted a cooperative rangewide survey. The technique used in this survey was to count all the accessible nearshore areas within the sea otter's range from the ground. Inaccessible areas were counted by aerial observers. This type of survey, without an assessment of the number of animals missed, is strictly enumerative and useful for establishing rangewide trends when conducted over a sufficiently long period.

RESULTS

Rangewide Surveys

The first rangewide survey encompassed by this report (1977-1983) took place in June, 1979, and was an aerial survey with ground truth stations. Eighty-seven ground truth stations, of the 110 designated, were occupied during the three-day survey. Fifteen of the occupied stations were not utilized in computations because otters were not observed within station boundaries at the time of the aerial count.

Aerial observers counted independent sea otters between Gaviota and Pigeon Point. Of these, 164 were counted between Shell Beach and Point Sierra Nevada during the first day. A comparison with the ground truth effort (n=25 stations) revealed that aerial observers counted 50.3% of the sea otters counted by ground observers (Table 1). During the second day aerial observers counted 297 independent otters between Point Sierra Nevada and Point Sur. A comparison with the ground truth effort (n=24 stations) revealed that aerial observers counted 50.5% of the otters counted by ground observers. Aerial observers counted 332 independent sea otters between Point Sur and Ano Nuevo Island during the third day of the survey. A comparison with the ground truth effort (n=23 stations) revealed that aerial observers counted 59.3% of the sea otters counted by ground observers. An additional 325 independent otters, not noted by aerial observers, were counted by ground observers within the 72 ground truth stations for a combined count of 1,118 independent sea otters tabulated rangewide.

Sea otter pups (large and small) were tallied separately. Aerial observers counted 34 pups during the three-day survey. Twelve of these were observed within ground truth stations. A comparison indicated that aerial observers counted 21.4% of the pups counted by ground observers. Aerial and ground counts, combined, yielded 78 pups for a total of 1,196 sea otters counted rangewide.

Estimated numbers of independent sea otters within each survey area (95% confidence limits - CI) were 326 (CI 283 - 384), 588 (CI 530 - 661) and 560 (CI 515 - 613) (Table 1) (Geibel and Miller 1984). The total estimated number of independent sea otters was 1,443 (CI 1,357 - 1,537) for the three days combined. The estimated number of sea otter pups for the three days combined was 159 (CI 96 - 459). Estimated numbers of independent and pups combined totaled 1,602 (CI 1,453 - 1,996).

Weather conditions during the three-day survey, although extremely variable, were generally poor. Aerial and ground observations were frequently hampered by strong winds (25+ knots), fog, or a combination of both. Because of concern about the precision of the otter counts, subsets of the data were analyzed separately. Recent ground counts were available from three areas for comparison.

Ground counts within a 12 km area at the southern periphery of the range, between Pismo Beach pier and Point San Luis, varied between 51 and 83 sea otters during May and June 1979 (Table 2). The number estimated to be within that area, using the 1979 rangewide survey data, was 47 (CI 42 - 52). The area just north of Point San Luis, between Rattlesnake Creek and Coon Creek (approximately 16 km) was surveyed periodically in conjunction with Diablo Canyon Nuclear Power Plant ecological studies (Benech 1979). Ground counts there, in June 1979, ranged between 51 and 65 sea otters. The number estimated from the rangewide survey data to be there was 45 (CI 29 - 97). A third area, within the well established portions of the range, between south Cambria and Point San Simeon (13 km) was surveyed in May 1979. That survey yielded a count of 126 apparently independent sea otters. The number estimated to be there during the June 1979 rangewide survey was 118 (CI 72 - 338). All three comparisons suggest that the 1979 rangewide estimate was low.

Index Area Surveys

Aerial and ground surveys of selected index areas were initiated in April 1980. Numerous surveys, however, were previously conducted in several of these areas. The primary objective of this type of survey was to monitor sea otter numbers to detect trends in population size through time.

Index Area 1 (Del Monte Kelp south 19 km to Cypress Point) (Figure 2): Eight aerial surveys were conducted within this index area between June 1980 and October 1981 (Table 3). Counts ranged from 77 to 147 sea otters including pups. The mean number observed was 116 (SD 26.4). Eleven ground surveys were conducted between April 1980 and April 1983. These counts ranged from 100 to 219 sea otters including pups. The mean number observed was 145 (SD 36.1).

Several of these aerial and ground surveys were conducted concurrently (the same day). On June 6, 1980, 147 sea otters were counted from the air and 219 from the ground (195 independent). On May 14, 1981, 110 sea otters were counted from the air and 171 from the ground (149 independent otters). Aerial observers counted 67 and 64% of the total counted by ground observers. Both percentages increase to 74% when pups were excluded.

To assess the utility of using index area surveys to detect trends in population size an analysis was performed using aerial and ground counts made during 1980 to determine the number of replications (n) needed to detect a given "true" difference between means (Table 4). To detect a 10% change in population numbers (p=.8 at 95% confidence level) would require 121 aerial counts or 92 ground counts each year.

The number of sea otters observed during a ground survey in this index area ranged from 5.5/km to 11.5/km. The average number observed from all ground surveys combined was 7.6/km. The average number of independent otters observed was 128 or 6.8/km.

The observed ratios of pups to independent otters ranged from .04 to .18 (= 4 to 18 pups/100 independent otters). The mean ratio was .13. Ratios for small (wooley) pups to independent otters ranged from .01 to .12. There was no apparent seasonal trend in this ratio.

Index Area 2 (Malpaso Creek south 19 km to Little Sur River) (Figure 2): Ten aerial surveys were conducted here between April 1980 and October 1981 (Table 3). Counts ranged from 39 to 124 sea otters. The mean number observed was 85 (SD 31.8). Eleven ground surveys were conducted between April 1980 and April 1983; counts ranged from 61 to 128 sea otters. The mean number observed was 98 (SD 24.8). Two of the aerial and ground surveys were conducted concurrently. On June 5, 1980, 96 sea otters were counted by aerial observers while ground observers counted 128, 116 of which were identified as independent animals. On August 14, 1980, 104 sea otters were counted from the air and 127 from the ground (117 independent). Aerial observers counted 75 and 82% of those counted by ground observers. Both percentages increased to 78 and 87, respectively, when pups were excluded.

Given this degree of variability, 102 aerial counts or 95 ground counts each year would be needed to detect a 10% change in population numbers (p=.9 at 95% confidence level) (Table 4).

The number of sea otters observed during ground surveys ranged from 3.2/km to 6.7/km. The average number observed from all ground surveys combined was 5.2/km. The average number of independent otters observed was 87 or 4.6/km.

The observed ratio of total pups to independent otters ranged from .07 to .19 (= 7 to 19 pups/100 independent otters). The ratio from all ground counts combined was .12. Ratios of small pups to independent otters ranged from .03 to .09. There was no apparent seasonal trend to this ratio. However, surveys in July and August yielded the lowest ratios.

Index Area 3 (Limekiln Creek south 23 km to Villa Creek) (Figure 2): Ten aerial surveys were conducted within this index area between April 1980 and June 1983 (Table 3). Counts ranged from 43 to 123 sea otters. The mean number of sea otters observed was 85 (SD 27.3). Four ground surveys were conducted between April 1980 and August 1980; counts ranged from 105 to 144 sea otters. The mean count was 122 sea otters (SD 16.1).

Two of these aerial and ground surveys were conducted concurrently. Both were made in June 1980, one day apart. On June 4, 117 sea otters were counted by aerial observers and 144 by ground observers. On the next day aerial observers counted 123 sea otters and ground observers counted 120 sea otters. Aerial observers counted 81% and 102% of the total counted by ground observers. Both percentages increased to 89 and 109%, respectively, when pups were excluded.

An analysis was made, using data from 1980, to determine the number of counts needed to detect various "true" differences between mean counts. To detect a 10% change in population numbers (p=.8 at 95% Confidence level) would require 64 aerial or 25 ground surveys each year (Table 4.).

The number of sea otters observed during ground surveys ranged from 4.6/km to 6.3/km. The average number observed from all ground surveys combined was 5.3/km. The average number of independent otters was 106 or 4.6/km.

The observed ratios of total pups to independent otters ranged from .09 to .23 (= 9 to 23 pups/100 independent otters). The ratio from all counts combined was .15. Ratios of small pups to independent otters ranged from .06 to .14. The August 1980 survey yielded the lowest small pup to independent otter ratio.

Index Area 4 (Point San Simeon south 13 km to south Cambria) (Figure 2): This area was surveyed on numerous occasions after January 1977, however, only counts obtained after April 1980 were utilized in this analysis. Twelve aerial surveys were conducted between April 1980 and June 1983 (Table 3). Counts ranged from 51 to 134 sea otters. The mean number observed was 91 (SD 25.1). Sixteen ground surveys were conducted between May 1980 and November 1982 (Table 3). Counts ranged from 80 to 169 sea otters. The mean was 115 (SD 22.9). There were no concurrent air and ground counts within this area.

An analysis of counts obtained during the 1980 surveys indicated 108 aerial or 55 ground counts would be necessary

each year to detect a 10% change in mean counts (p=.8 with 95% confidence) (Table 4).

The number of sea otters observed during a ground survey ranged from 7.2/km to 13.0/km. The average number observed from all surveys combined was 8.8/km. The average number of independent sea otters was 97 (SD 18.7) or 7.5/km.

The ratios of total pups to independent otters ranged from .06 to .29 (= 6 to 29 pups/100 independent otters). The ratio from all counts combined was .18. Ratios of small pups to independent otters ranged from .01 to .17. The ratios were generally highest in late winter-early spring and lowest in late summer-early winter.

All ground survey counts (1977 to 1982) from index area 4 were summarized by year to determine if trends would be apparent by assessing a larger data base (Table 5). The mean counts by year ranged from 99 sea otters in 1978 to 124 in 1979. The mean counts of independent sea otters by year ranged from 108 in 1979 to 85 in 1982. The mean count of all otters and for independent otters from all years combined was 112 (SD 21.0) and 96 (SD 17.8), respectively. Regression analysis of log-transformed counts of total otters on months, yielding a slope of .0003, indicated no change in numbers (Figure 3).

Although no change in the number of sea otters counted within this index area from 1977 through 1982 was apparent, there were extended periods when all or most counts fell above or below the grand mean. All counts, for example, from September 1977 through August 1978 (n=8) were well below the mean. Most counts from September 1978 through July 1981 (16 of 21) were above the mean. These data suggest that cyclic fluctuations occurred about the mean, despite variation due to counting error.

Analysis of small pup to independent otter ratios by year suggests that pup production did not change significantly from 1977 through 1982 (Kruskal-Wallis H = 6.72; Chi-sq .05(5) = 11.07). These ratios varied from .11 in 1977 to .07 in 1979 (Table 6). Total pup to independent sea otter ratios ranged from .13 in 1978 to .21 in 1982.

The mean ratios of small pups to independent otters from all years combined, by month, indicated a peak in occurrence of small pups in February and March (Figure 4). There was also an indication of a secondary peak in September. This distribution was similar to the seasonal distribution of pupping inferred from rangewide observations of tagged sea otters (Wendell, Hardy, and Ames in press).

A rough approximation of pup production, within this index area, for an "average" year was derived using this distribution. Our observations of tagged mothers and pups indicate that the

transition from small to large pup, based on the presence or absence of natal pelage, although somewhat variable, occurs approximately 10 weeks after birth. The probability of an observed small pup being born on any given day is 0.0143 (1/70), or roughly 0.43 of being born during a month (30 days x 0.0143). Annual pup production for this index area, using this probability and the averaged count of small pups by month, was roughly 43 pups per 100 independent otters.

Peripheral Range Index Areas (Figure 2): The northern and southern portions of the sea otter's range in California was surveyed periodically to monitor seasonal and annual changes in number and distribution within these areas. Aerial surveys in these areas and beyond were initiated early in 1977.

Thirty-seven aerial surveys were completed through the end of 1983 between Marina and Point Ano Nuevo at the northern end of the range (Table 7). Counts ranged from a low of 18 sea otters in December 1977, to a high of 99 in February 1982. A seasonal grouping of these counts (February - May vs August - November) indicated some seasonality in numbers counted. The mean count for surveys conducted from February through May (n=17) was 58 sea otters (SD 18.2). The mean count from August through November (n=11) was 46 sea otters (SD 17.5). A comparison of means indicated the observed difference was statistically significant (t=1.74 16df p(.05)).

Detecting longer-term trends in the number of otters occupying the northern portion of the range would be facilitated by moderating the influence of season. This was accomplished by adjusting each count by subtracting the corresponding mean monthly count (Figure 5). The difference was regressed on month. The regression yielded a slope of 0.254 which deviated significantly from zero (t ratio = 2.56 p(.025)), suggesting there has been an increased utilization of the northern portion of the range by sea otters. The markedly higher counts from 1982 on, suggest that the increase was abrupt rather than a gradual change.

The location of the largest group of males at the northern end of the range, which we have used to demarcate that range limit, did not change through the period covered in these surveys. The number of otters counted beyond this group, however, increased through time (Table 7) and perhaps represents a northward extension of the range to Point Ano Nuevo.

Thirty-four aerial surveys within the southern peripheral portion of the sea otter's range between Morro Rock and Point Sal were completed by the end of 1983 (Table 8). Counts ranged from a low of 21 sea otters in December 1977, to a high of 144 in April 1980. Seasonally grouped survey data (February-May vs August-November) indicated there was a marked difference in numbers of otters counted between the two periods. The mean count for surveys conducted from February through May

was 115 sea otters (n=16) and 62 sea otters (n=7) for surveys conducted from August through November. A comparison of means indicated the observed difference was statistically significant (t=6.2 21df p(.001)).

Regression of counts, adjusted to control the influence of season, on month yielded a slope of .014 which did not deviate significantly from zero (t ratio = 0.12) indicating no change in numbers had occurred within that area from 1977 through 1983 (Figure 6). The mean count of sea otters, including pups, within this area in the vicinity of the Diablo Canyon Nuclear Power Plant, however, did indicate an increase in the number of reproductive females and pups (Benech and Colson 1976; Benech 1982; Gotshall et al. 1986).

The seasonal occurrence of a large peripheral male group in the winter was largely responsible for the seasonal changes in numbers of sea otters counted. The southernmost rafting site was located off Pecho Rock in 1977 and 15 km south at Shell Beach in 1979. Between 1979 and 1983, this large peripheral male group, when present, continued to raft off Shell Beach (with the exception of 1981, when the group remained off the Morro Sand Spit), but extended their foraging area 23 km south to the Santa Maria River (Wendell, Hardy, and Ames in press).

Extralimital sightings were more common to the south than to the north, but never exceeded eight otters. Individuals were reported from as far south as San Diego and as far north as Cape Mendocino.

Ground surveys of the nearshore area south of Point San Luis were initiated in February 1979 when the large peripheral male group moved into that area. Thirty-four surveys were conducted through September 1981 (Table 9). The counts from this area also showed a marked seasonal change in numbers with a rapid increase in January or February of each year and a rapid decrease in May or June. A difference between years was apparent in both maximum and minimum numbers counted. More otters were counted during the summer-winter period (minimum) in 1979 with fewer observed each succeeding year. The number counted during the winter-spring (maximum) period was highest in 1980.

A comparison of these ground counts with aerial counts from Point San Luis to the Santa Maria River showed remarkably similar numbers through February 1981. Several aerial surveys after that yielded higher counts. A large number (31 and 26) of otters were observed, during these flights, at or beyond the southern limit of the ground count area (Oso Flaco Creek) and many were located far offshore.

Rangewide Ground Counts with Aerial Support

During the spring of 1982 (March 23 to May 26) biologists from

the USFWS surveyed a large portion of the sea otter's range in California from the ground (Estes and Jameson 1983). The number of sea otters counted was combined with aerial and boat counts, and estimates from aerial counts for the remaining portion of the range to yield a total "count" of 1,346 otters (1,124 independent and 222 pups).

Three rangewide surveys have been completed, in a cooperative USFWS and CDFG effort, since that time using only ground counts or, in less accessible areas, aerial counts. The first cooperative survey began on November 16, 1982 and was completed in 11 days. Counting conditions varied from good to excellent, with moderate to large ocean swell being the only adverse condition noted on most observation days. Aerial observers counted 256 sea otters (254 independent and 2 pups) within areas deemed inadequate for ground surveys. Ground observers counted 1,082 otters (940 independent and 142 pups), for a total count of 1,338 otters (1,194 independent and 144 pups). The second survey began on June 21, 1983 and was completed 25 days later. Counting conditions varied but were generally considered good, with moderate swell and partial overcast. Aerial observers counted 306 sea otters (298 apparently independent otters and 8 pups). Ground observers counted 969 otters (855 independent and 114 pups) for a total of 1,275 sea otters (1,153 independent and 122 pups). The aerial portion of this survey included 15.5 km of coastline counted by ground observers in November 1982. The third survey commenced on October 24, 1983, and was completed in 6 days. Counting conditions varied from fair to excellent, with moderate swell, clear sky and generally moderate wind (10-15 kts). Aerial observers counted 284 sea otters (278 independent and 6 pups). Ground observers counted 940 otters (784 independent and 156 pups) for a combined count of 1,224 sea otters (1,062 independent and 162 pups). Two small sections (18 km) of coastline were not surveyed, and an additional 8.5 km was aerially surveyed.

The rate at which teams surveyed sections of coastline on a daily basis during the November 1982 survey varied from 1.8 km/hr to 5.6 km/hr.

A ground counting consistency test was conducted prior to the first of these surveys. During this test, six two-member teams, comprised largely of individuals likely to participate in rangewide counts, counted otters along a 6.4 km stretch of coastline within the middle of the otter's range. Counts were initiated from both ends of the test section with starting times spaced at 15-minute intervals. Sea otter location and behavior were noted on maps for subsequent analysis.

Starting times varied from 0852 (PST) to 0945 hours. Total count time varied from 3.1 hours to 4.7 hours (2.1 km/hr to 1.4 km/hr). The number of sea otters counted ranged from 32 to 48, a difference of 33%. The average number of otters missed, comparing each count to the highest count, was 15%.

Another estimate of the proportion of otters missed using the same data was made using a modified mark-recapture estimator described by Geibel and Miller (1984). Four comparisons of otter counts and distribution were made. The data were grouped by time to minimize error from movement. The first count provided a tagged distribution and the second provided recapture data. Estimates varied from 7% to 33% otters missed, with an average of 18% missed under these viewing conditions.

DISCUSSION

Rangewide Surveys - Historical

Although the CDFG made counts at periodic intervals for approximately 10 years following the "rediscovery" of sea otters in California in 1938, the first systematic rangewide survey was not completed until August 1957 (Boolootian 1961). That survey, conducted over an unknown period of time, was conducted from a helicopter. Counts of isolated individual otters and small groups were supplemented with counts from photographs of large groups. A total of 638 sea otters was counted during that survey.

Miller (1958) conducted the next survey on May 23, 1958, from a single engine Cessna. He counted 176 sea otters.

The next rangewide survey was not completed until January 29, 1964. Independent counts were made from a twin engine Beechcraft, an airplane with a higher minimum flying speed than a Cessna, and supplemented with photographs of all sizable groups. The same type of survey was conducted in February and again in May of that year. The averaged independent observer count ranged from 236 sea otters in January to 387 in May. The highest count was 396 sea otters (Carlisle 1964). These single day aerial surveys conducted from the Beechcraft continued, with some changes in personnel, through 1965. Four surveys were completed that year with the averaged counts ranging from 137 sea otters in February to 497 in June. The highest count was 499 sea otters.

From June 1966 through March 1969, aerial surveys were conducted from a single engine Cessna 182, which provided reduced air speed and improved visibility. The 1966 June survey, conducted by the same CDFG personnel who counted in 1965, yielded an average of two counts of 591 sea otters (565 and 618) (Carlisle 1965). Two aerial surveys in 1967 conducted without major changes in personnel or techniques, yielded an averaged count of 537 sea otters in June, and 562 in October.

The highest count was 565 sea otters. The June 1968 survey was the last before a major change in personnel occurred. The average of two counts was 576 sea otters (575 and 577).

In August 1968, with new personnel conducting the survey, all observations were combined in a single count. A total of 310 sea otters was counted on that flight. Five subsequent aerial surveys through March 1969, yielded counts ranging from 377 sea otters in December 1968, to 983 in January 1969.

In June 1969, CDFG personnel switched to a twin engine Cessna Skymaster to conduct rangewide aerial surveys. Although the Skymaster must fly faster than the single engine Cessna, the change was made based on safety considerations. A total of 12 surveys was completed through October 1971 without major changes in personnel or technique. Counts ranged from a low of 435 sea otters in September 1969, to a high of 1,040 in May 1970.

From January 1972 on, all rangewide aerial surveys were conducted over a two or three day period. Two of these, the January and April 1972 surveys, incorporated no other changes. The counts for those surveys were 1,060 and 770 sea otters, respectively.

Ground truth stations, developed to assess the proportion of sea otters missed by aerial observers, were first incorporated into the sampling design during the December 1973 rangewide survey. A total of 1,103 sea otters was counted; 941 sea otters were counted from the air and an additional 162 were counted by ground observers.

The next five surveys, conducted from March 1974 through June 1976, were conducted over a three day period and included some new personnel. The number of ground truth stations occupied generally increased through June 1976. Total counts ranged from 895 sea otters (no ground truth) in April 1975 to 1,560 (1,220 independent and 360 pups) in June 1976.

The changes in rangewide survey techniques from 1957 through 1976 were initially made to improve the accuracy of aerial counts and subsequently to assess the number of sea otters still missed by aerial observers. Although these changes were effective, they also introduced sources of variation to be considered when comparing survey results.

Rangewide Surveys - Recent

The estimated percent of animals counted by aerial observers within ground truth stations was low for independent sea otters during the 1979 survey when compared with the 1976 survey (55% vs 64%) and notably higher for pups (21% vs 8%). The difference in percent of independent otters counted

during the two surveys could be attributed to poor viewing conditions during 1979. The higher percent of pups counted by aerial observers in 1979 would seem to argue against this supposition since pups are inherently harder to observe. However, there was a change in the way pups were defined between the 1976 and 1979 surveys. In 1976 otters were tallied as either free-swimming otters or clinging pups. Typically, only some of the small pups would be included in the clinging catagory. Otters were tallied simply as independent or pup during the 1979 survey. Large pups and non-clinging small pups were still considered pups and this difference would tend to overestimate the number of independent or adult otters in 1976.

The 1979 survey results with a population estimate roughly 19% lower than the 1976 estimate, raised questions regarding the reliability of the census technique and the status of the sea otter population.

Ground observers may not have provided an adequate assessment of the actual number of sea otters within "truth" stations because of the poor observation conditions during much of the 1979 survey. So the difference in the estimated numbers of sea otters in 1976 and 1979 could be due, in part, to conducting the 1979 survey in unsuitable weather. Estimates from the three subsets of the 1979 rangewide survey data, when analyzed separately and compared to ground counts from those areas, were all lower, suggesting that the estimates were biased low (see results).

Index Area Surveys

Meetings were held with the CDFG Sea Otter Scientific Advisory Committee following the 1979 survey to discuss the techniques used and objectives behind the censusing of sea otters in California. The need to improve confidence in the reliability of the survey data was obvious. It was generally concluded that a more biologically tenable objective would be to assess trends in population abundance by intensively surveying preselected segments of the range.

The index area surveys and the USFWS rangewide ground counts were conducted to provide data with which to assess trends in population abundance. The variability in numbers of sea otters counted within index areas was large enough to preclude the use of index area counts to detect modest changes in abundance on an annual basis. The recent rangewide ground counts, on the other hand, have provided surprisingly consistent data.

Counts within small portions of the range (index areas), if conducted consistently through time, can be utilized to detect trends in size of the population. Three areas, two at the range periphery and one within the range, have been surveyed

fairly consistently since 1977. Regression analysis of log-transformed counts on month or adjusted counts on month showed only one statistically significant change in numbers within these areas since 1977.

A preliminary analysis of combined CDFG and USFWS count data from several of the index areas within the established portion of the sea otter's range suggest a rather remarkable stability in the long-term occupied range (Ebherhardt, pers. comm.). However, the results did suggest a small decline in 1977 and 1978, and a cyclic trend thereafter.

Sea Otter Population Status

An evaluation of the status of the sea otter population in California based only on rangewide survey data will be somewhat subjective. Rather marked changes in survey techniques have occurred, introducing variability in the data. This is particularly important given the apparent low rate of population growth for sea otters in California.

The 1982 and 1983 rangewide ground counts with aerial support were much lower than either the number estimated or counted during the 1976 survey. Since the 1979 rangewide survey also yielded a count and estimate lower than that obtained in 1976, a decline in population numbers between 1976 and 1982 was possible.

In order to further evaluate this possibility, data from all rangewide surveys back to 1974 were reanalyzed to make them optimally comparable to the 1982 and 1983 rangewide ground counts. There was no overlap of aerial and ground count areas in the 1982 and 1983 counts. The reanalysis of prior survey data excluded all otters counted by aerial observers within ground truth stations, and separated all identified pups from independent otters. The reanalysis tended to moderate the differences between survey techniques and consequently the results. However, potentially significant variables still remain unaccounted for.

The presence or absence of mature bull kelp, Nereocystis, at the surface during a survey, is an example of one such variable. Otters are more difficult to see while in bull kelp. During the spring and early summer (June 1976 survey), these plants are scarce at the surface. However, they are typically quite abundant in the late summer and fall period (November 1982 and October 1983 surveys). The severity of the 1982-83 winter storms further complicated comparisons, since dramatic reductions in the abundance of canopy-forming kelps occurred which would also influence sea otter distribution and countability.

Seasonal changes in sea otter distribution could also contribute to differences in countability. The southern peripheral male group which normally disperses by early summer, had not completely dispersed when counts were made in June 1976, but had dispersed back into the range by the November survey in 1982.

The rangewide ground counts from 1982 on were as good as those which preceded because a larger proportion of the range was surveyed from the ground and thus a higher proportion of otters were likely counted. This contention was used to support the suggestion that the population had undergone a modest decline since 1973 (Estes and Jameson 1983). We have mentioned several variables unaccounted for in this contention which could influence countability. The variation in numbers of sea otters counted during recent rangewide aerial strip census efforts (Estes, pers. comm.; Bonnell, pers. comm.) support the notion that seemingly subtle differences in viewing conditions can markedly influence the number of sea otters counted. Several of the sources of variability mentioned here could account for the differences in the number of sea otters counted during the 1976 survey and later surveys if the population sizes were similar. However, it seems obvious that the anticipated population growth since 1973 has not occurred.

We conclude, based on both the index area survey data and the rangewide survey data, that there have been no demonstrable changes in population size since at least 1976. Data from index area four, within the longer established portion of the sea otter's range, suggest there have been no marked changes in pup production during the interval from 1977 to 1982. Since pup production has remained fairly constant from year to year without notable increases in sea otter numbers in newly reoccupied range, it seems likely that mortality has increased. Ames, et al. (1983) mention a number of mortality sources (natural and man-caused) which could influence population growth.

Interpreting survey data in the future would be facilitated if survey methodologies were both standardized and sufficiently accurate to satisfactorily estimate population size or trends. At present ground counts within index areas provide the best indicator of population trends and annual pup production. Rangewide ground counts with aerial support will become more useful as that data base increases in size. The utility of rangewide ground counts with aerial support to satisfactorily estimate population size will depend on developing methods to estimate the number of animals missed (truthing) as part of the actual survey and standardization of the portion of the range to be surveyed from the air. At the present time rangewide aerial counts with ground truth stations provide the best available data for estimating total population size.

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FIGURE 1. A Census Map showing location, number and behavior of sea otters.

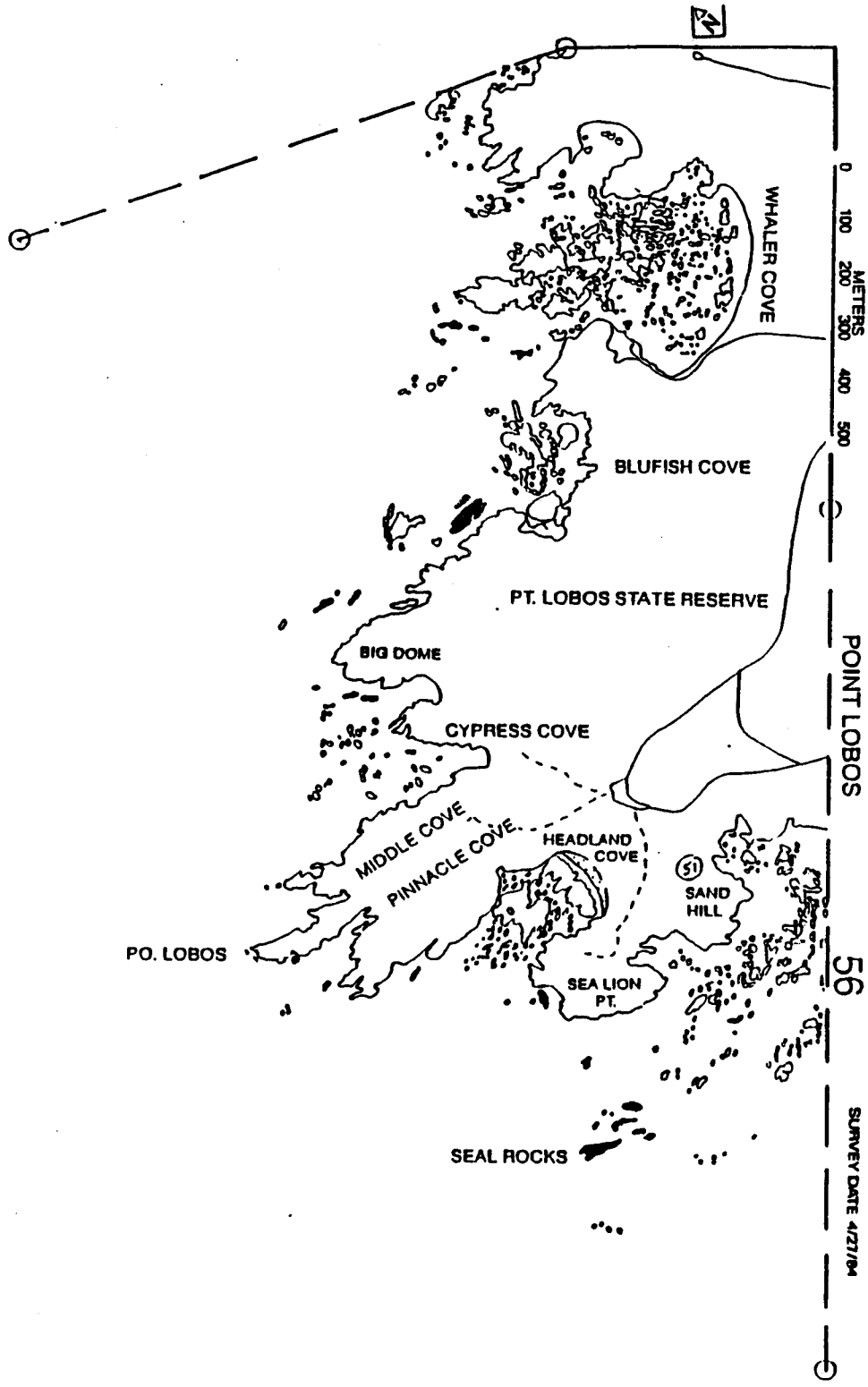


FIGURE 2. Location of index areas and limits of peripheral survey areas.

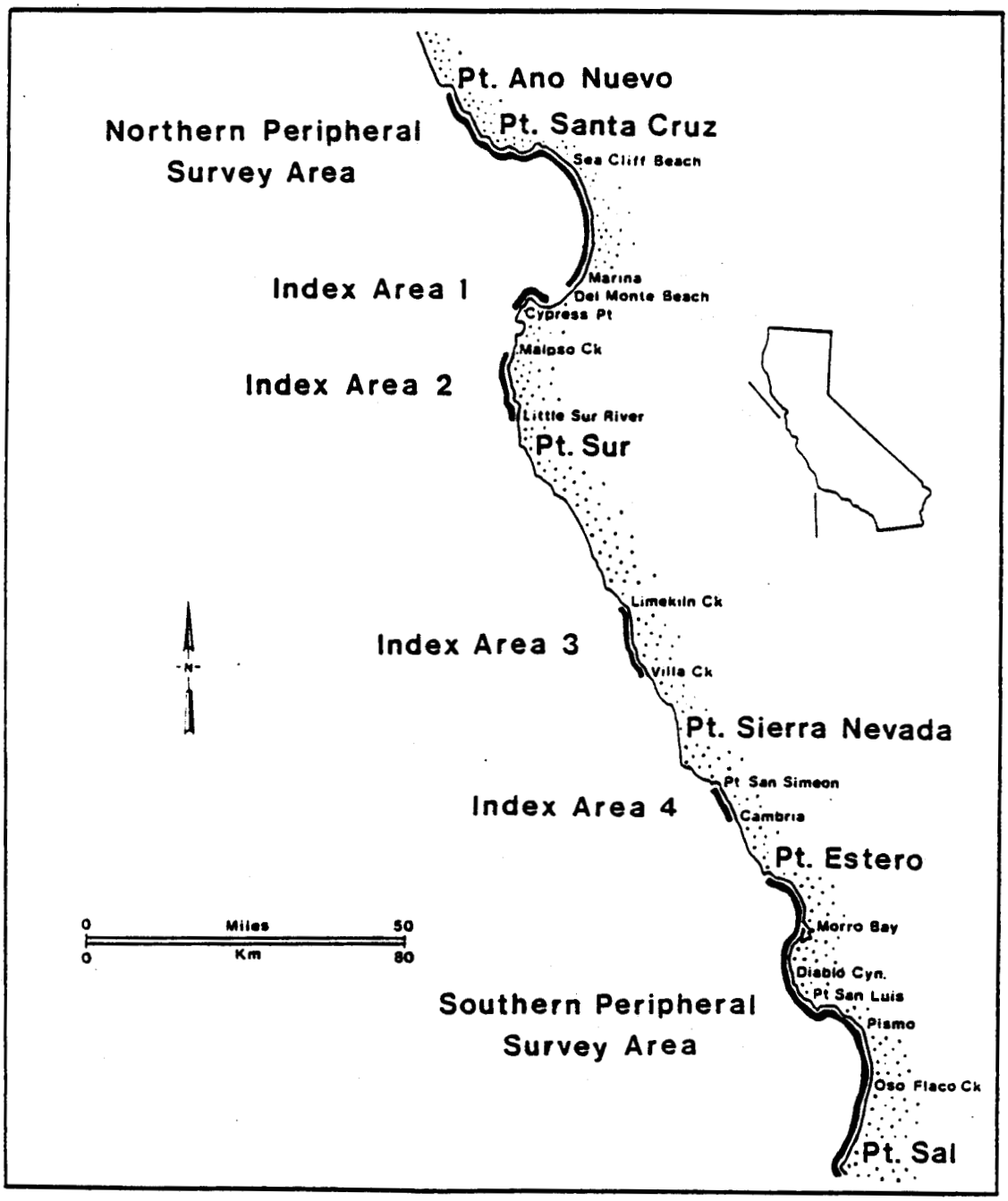
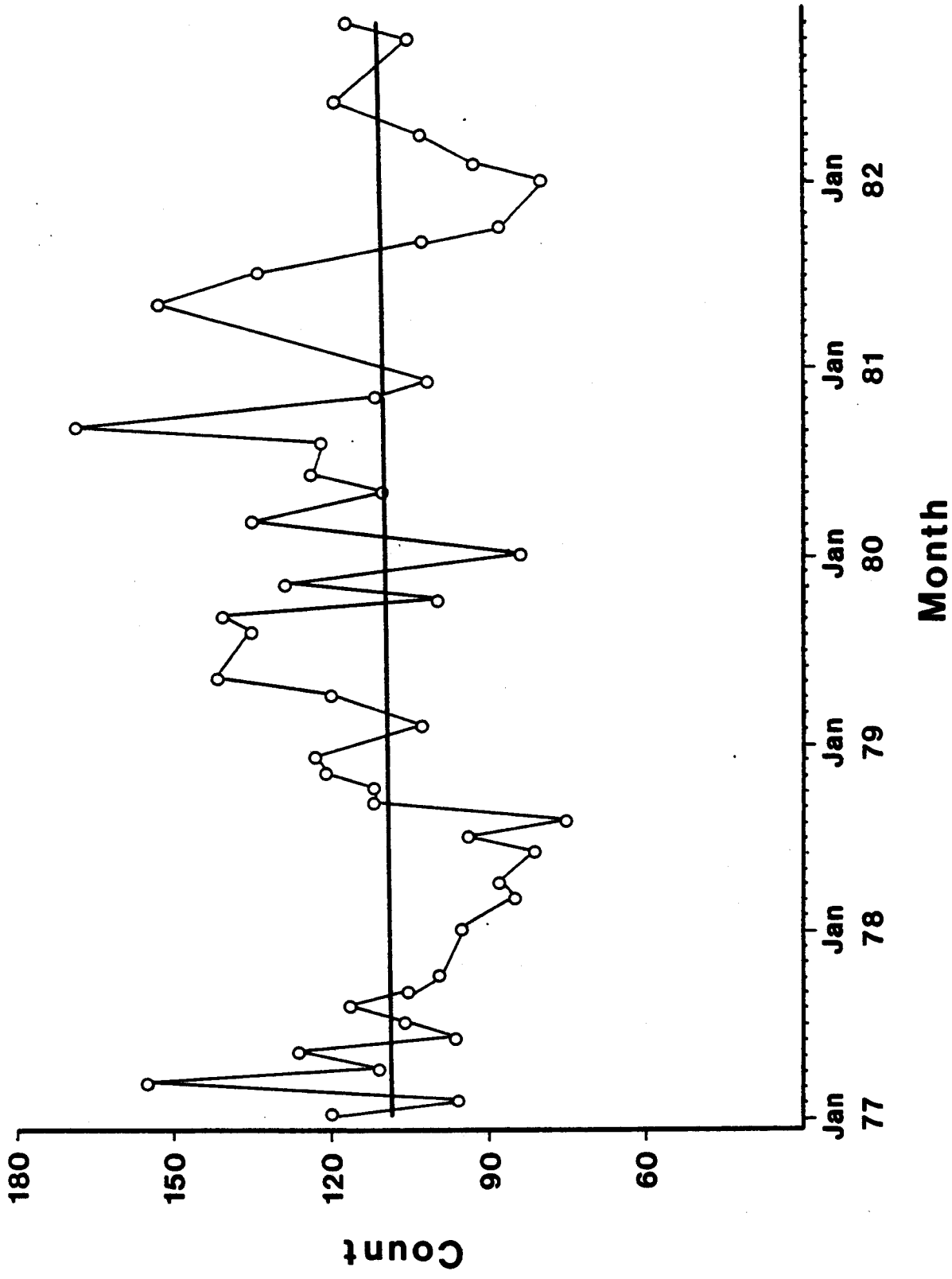


FIGURE 3. Counts of sea otters between Point San Simeon and South Cambria. Regression of log-transformed counts of otters on month did not deviate significantly from zero.



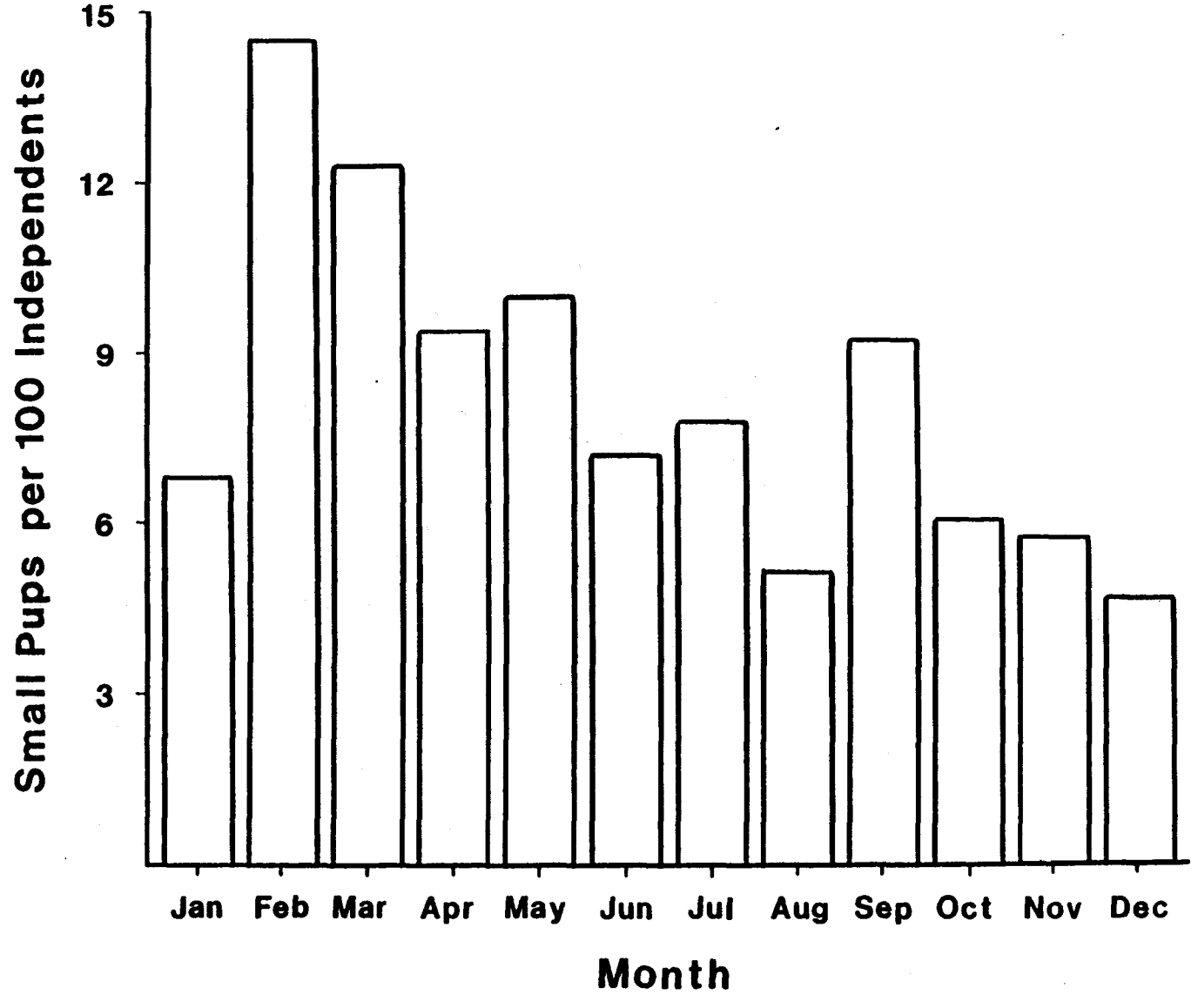


FIGURE 4. Mean of small pups per 100 independent sea otters by month, index area 4 from 1977 through 1982.

FIGURE 5. Adjusted counts (monthly count minus mean count for that month) of sea otters within the northern peripheral survey area between February 1977 and October 1983. The regression line, with a slope of .254, deviated significantly from zero.

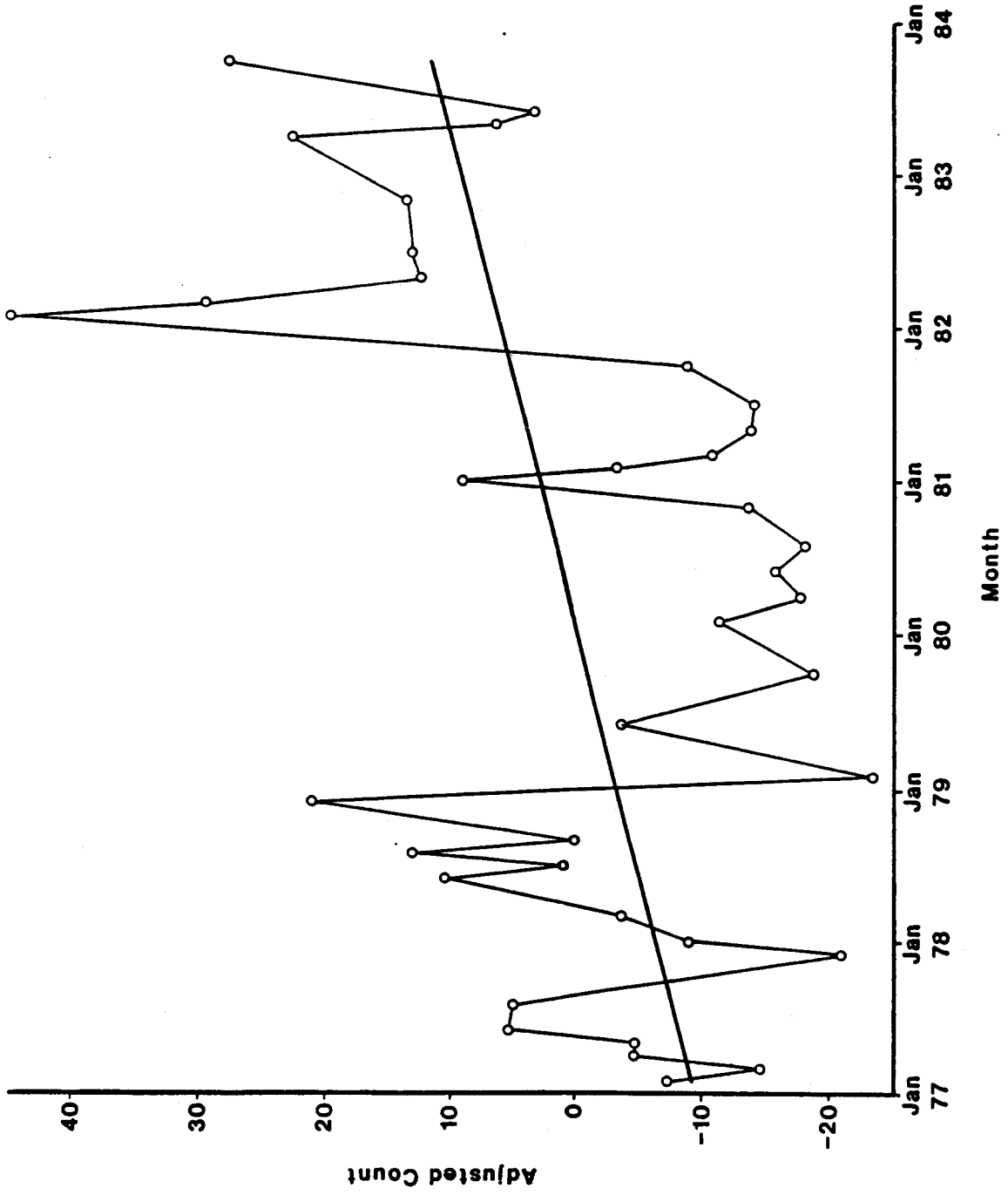


FIGURE 6. Adjusted counts (monthly count minus mean count for that month) of sea otters between March 1977 and October 1983. The regression line, with a slope of .014, did not deviate significantly from zero.

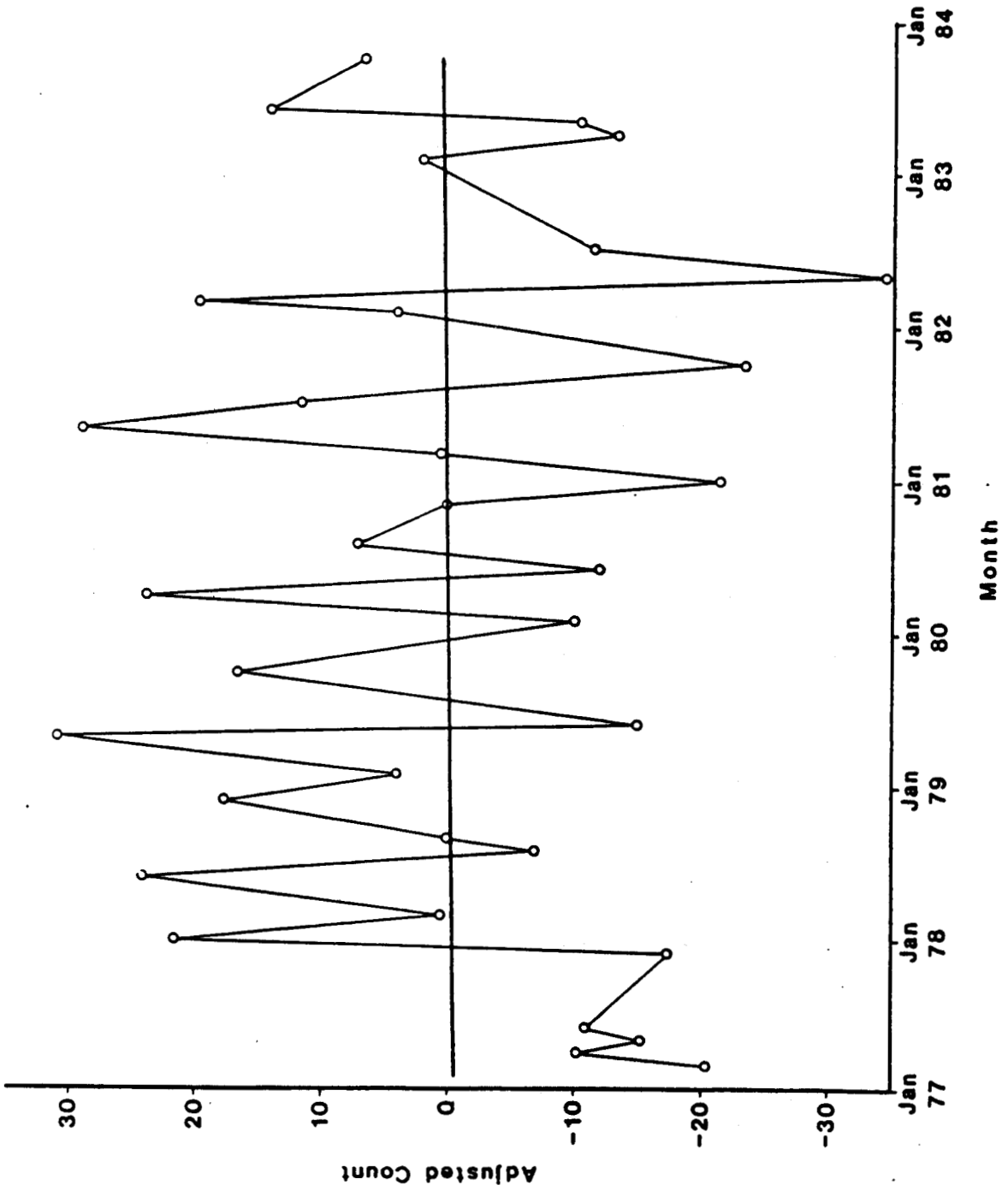


TABLE 1. Rangewide Sea Otter Survey, 1979.

Date	Aerial Count	# Truth Stations	Ground Count	Aerial/Ground Common Count	$\hat{p}$*	N	95% Confidence Limits
Independent Otters -							
27 June	164	25	155	78	.503	326	283-384
28 June	297	24	192	97	.505	588	530-661
29 June	332	23	376	223	.593	560	515-613
All Days Combined	793	72	723	398	.550	1443	1357-1537
Clinging Pups -							
All Days Combined	34	72	56	12	.214	159	96-459

* $\hat{p}$ Equals proportion of otters counted by aerial observers within truth stations.

TABLE 2. Ground Counts Within Selected Portions of the Sea Otter's Range Compared With Estimates From the 1979 Rangewide Survey.

Area	Coastline Length	Ground Counts	Date	1979 Rangewide Survey Estimate (CI)
Pismo pier to Pt. San Luis	12 km	51-83	May and June 1979	47 (42-52)
Rattlesnake Ck. to Coon Ck.	16 km	51-65	June 1979	45 (29-97)
South Cambria to Pt. San Simeon	13 km	126	May 1979	118 (72-338)

TABLE 3. Aerial and Ground Counts of Sea Otters (Independent animals + pups) Within Four Index Areas.

Index Area	Length	Aerial Date	Aerial Count	Ground Date	Ground Count
Del Monte Beach to Cypress Pt.	19 km	6- 4-80	100+1	4- 9-80	161+16
		6- 5-80	134+3	6- 6-80	195+24
		6- 6-80	144+3	7- 3-80	136+ 5
		7-15-80	75+2	11-11-80	105+11
		11-13-80	84+4	3- 9-81	96+15
		5-14-81	110+0	5-14-81	149+22
		7-29-81	146+0	7-20-81	139+21
		10-15-81	115+6	10-14-81	110+20
				2- 5-82	89+11
				6-11-82	133+23
				4-11-83	98+12
Malpaso Ck. to Little Sur R.	19 km	4- 8-80	58+1	4- 7-80	64+ 8
		6- 4-80	107+1	6- 5-80	116+12
		6- 4-80	114+3	8-14-80	117+10
		6- 5-80	90+6	11-12-80	102+15
		6- 6-80	123+1	3-11-81	56+ 8
		8-14-80	102+2	5-13-81	83+ 8
		11-13-80	100+1	7-22-81	91+ 7
		5-14-81	58+2	10-21-81	90+17
		7-29-81	42+0	2- 4-82	109+14
		10-15-81	38+1	6-14-82	73+10
				4-11-83	57+ 4

TABLE 3. Continued

Index Area	Length	Aerial Date	Aerial Count	Ground Date	Ground Count
Limekiln Ck. to Villa Ck.	23 km	4- 8-80	72+5	4- 7-80	98+23
		4-10-80	85+2	6- 4-80	126+18
		6- 4-80	112+5	6- 5-80	105+15
		6- 5-80	115+8	8-19-80	96+9
		6- 6-80	89+7		
		8-15-80	103+3		
		11-13-80	69+0		
		5-14-81	83+2		
		10-14-81	45+0		
		6- 8-83	42+1		
San Simeon pier to South Cambria	13 km	4- 8-80	57+5	5- 9-80	88+22
		4-10-80	69+6	6- 3-80	108+16
		6- 4-80	106+7	8- 4-80	106+16
		6- 5-80	99+7	9- 8-80	141+28
		6- 6-80	98+11	11-17-80	102+10
		8-15-80	127+7	12-15-80	96+6
		11-13-80	94+0	5-28-81	123+30
		5-14-81	101+15	7-30-81	117+17
		7-28-81	72+2	9- 3-81	88+15
		10-14-81	50+1	10-19-81	74+14
		2-10-82	63+7	1-13-82	74+6
		6- 8-83	85+8	2- 4-82	75+18
				4- 7-82	84+19
				6-24-82	100+19
				10-22-82	87+18
				11-16-82	91+26

TABLE 4. Number of Replications (n) Needed to Detect a Given "True" Difference ( ) Between Means. Data are from Aerial and Ground Counts During 1980 in Four Index Areas. A Significance Level of .05 Was Used With a Probability (P) That the Significance Will be Found if it Exists.

Index Area 1: Del Monte Beach to Cypress Point

Aerial Counts (7) x = 96.4 s = 25.2			Ground Counts (6) x = 115.8 s = 21.5		
P		n	P		n
.80	.05	480	.80	.05	367
.80	.10	121	.80	.10	92
.80	.20	31	.80	.20	24
.80	.25	20	.80	.25	16
.80	.50	6	.80	.50	5
.95	.25	33	.95	.25	25

Index Area 2: Malpaso Creek to Little Sur River

Aerial Counts (6) x = 98.7 s = 25.0			Ground Counts (4) x = 104.0 s = 25.4		
P		n	P		n
.80	.05	405	.80	.05	377
.80	.10	102	.80	.10	95
.80	.20	26	.80	.20	24
.80	.25	17	.80	.25	16
.80	.50	5	.80	.50	5
.95	.25	28	.95	.25	26

TABLE 4. Continued

Index Area 3: Limekiln Creek to Villa Creek

Aerial Counts (8) x = 95.0 s = 19.1			Ground Counts (6) x = 111.5 s = 13.7		
P		n	P		n
.80	.05	254	.80	.05	96
.80	.10	64	.80	.10	25
.80	.20	17	.80	.20	7
.80	.25	11	.80	.25	4
.95	.25	18	.95	.25	7

Index Area 4: San Simeon pier to South Cambria

Aerial Counts (7) x = 96.4 s = 25.2			Ground Counts (6) x = 115.8 s = 21.5		
P		n	P		n
.80	.05	427	.80	.05	218
.80	.10	108	.80	.10	55
.80	.20	28	.80	.20	15
.80	.25	18	.80	.25	10
.80	.50	6	.80	.50	3
.95	.25	30	.95	.25	15

TABLE 5. Summary of Survey Data Collected Between San Simeon Pier and South Cambria (Index Area 4).

Year	# Surveys	Total Otters $\bar{x}$	(sd)	per linear mile	Independent $\bar{x}$	(sd)	per linear mile
1977	10	113.1	(17.8)	14.0	96.6	(15.0)	12.0
1978	10	98.6	(17.2)	12.2	87.5	(17.0)	10.8
1979	7	124.3	(17.3)	15.4	108.0	(16.8)	13.4
1980	8	119.8	(25.2)	14.3	103.8	(18.7)	12.8
1981	4	119.5	(29.4)	14.8	100.5	(23.4)	12.4
1982	6	102.8	(14.7)	12.7	85.2	(9.9)	10.5

TABLE 6. Small Pup per Independent Sea Otter Ratios by Month and Year From Surveys (n) Conducted Between San Simeon Pier and South Cambria (Index Area 4).

	Year						Monthly		
Month	1977	1978	1979	1980	1981	1982	$\bar{x}$	(sd)	n
Jan	.114	.106		.038		.013	.068	(.050)	4
Feb	.169		.120			.147	.145	(.025)	3
Mar	.132	.120		.117			.123	(.008)	3
Apr	.092	.105	.048			.131	.094	(.035)	4
May	.144		.063	.170	.081		.100	(.073)	4
Jun	.119	.042		.056		.070	.072	(.034)	4
Jul	.066	.125			.043		.078	(.042)	3
Aug	.057	.092	.059	.019			.052	(.037)	4
Sep	.102	.073	.108	.099	.080		.092	(.015)	5
Oct	.082	.028	.045		.068	.080	.061	(.023)	5
Nov		.027	.034	.049		.121	.058	(.043)	4
Dec		.073		.021			.047	(.037)	2
Yearly $\bar{x}$	.108	.079	.068	.071	.068	.094			
(sd)	.035	.037	.033	.053	.018	.049			
n	10	10	7	8	4	6			

TABLE 7. Aerial Counts Within the Northern Peripheral Portion of the Sea Otter's Range. Area 1 = Salinas River to Sea Cliff State Beach; Area 2 = Sea Cliff State Beach to Point Santa Cruz; Area 3 = Point Santa Cruz to Ano Nuevo Island.

Date	Area 1	Area 2	Area 3	Total
2- 8-77	36	8	3	47
3-21-77	5	33	8	46
4-20-77	6	41	7	54
5-10-77	12	39	3	54
6- 1-77	13	34	7	54
9-12-77	12	38	1	51
12- 7-77	10	7	1	18
1-24-78	3	22	4	29
3-28-78	19	35	3	57
6-15-78	7	45	7	59
7-17-78	11	43	8	62
8-30-78	11	43	5	59
9-20-78	9	34	5	48
12- 7-78	3	50	7	60
2-22-79	10	16	5	31
6-29-79	6	37	2	45
10-10-79	4	23	3	30
2- 6-80	5	30	8	43
4- 9-80	7	28	6	41
6- 5-80	3	28	2	33
8-14-80	3	25	0	28
11-12-80	11	22	1	34
1- 7-81	19	26	2	47
2-16-81	25	7	19	51
3-10-81	25	25	0	50
5-14-81	8	35	2	45
7-29-81	5	35	7	47
10-15-81	10	30	0	40
2- 9-82	43	52	4	99
3-10-82	38	47	5	90
5-11-82	28	31	10	71
7- 7-82	14	49	11	74
11-17-82	43	11	7	61
4- 5-83	35	18	28	81
5-24-83	30	24	11	65
6-29-83	17	21	14	52
10-24-83	30	24	22	76

TABLE 8. Aerial Counts Within the Southern Peripheral Portion of the Sea Otter's Range. Area 1 = Point Estero to Morro Rock; Area 2 = Morro Rock to Point San Luis; Area 3 = Point San Luis to Point Sal; Area 4 = Point Sal South.

Date	Area 1	Area 2	Area 3	Area 4	Total
3-21-77	68	88	3	0	159
4-20-77	13	111	2	0	126
5-10-77	82	89	0	0	171
6- 1-77	44	74	1	0	119
12- 6-77	77	19	2	0	98
1-24-78	121	74	2	0	197
3-28-78	118	111	1	0	230
6-16-78	92	108	2	0	202
8-29-78	101	56	3	0	160
9-21-78	111	61	3	1	176
12- 7-78	67	54	2	0	123
2-22-79	59	77	53	0	189
5-14-79	?	54	81	0	?
6-27-79	29	29	42	0	100
10-10-79	89	40	39	0	168
2- 6-80	66	39	74	3	182
4- 9-80	52	40	104	3	199
6- 4-80	78	25	49	0	152
8-15-80	72	48	23	2	145
11-12-80	57	25	22	1	105
1- 7-81	58	15	18	0	91
3-10-81	39	26	80	6	151
5-13-81	82	58	73	2	215
7-28-81	75	68	5	5	153
10-14-81	102	38	0	1	141
2- 9-82	77	122	5	3	207
3-10-82	95	119	7	5	225
5-12-82	66	60	6	4	136
7- 6-82	56	39	13	3	111
2-16-83	76	67	59	2	204
4- 5-83	68	55	47	8	178
5-23-83	60	46	46	2	154
6- 8-83	66	52	44	4	166
10-24-83	67	54	12	3	136

TABLE 9. Ground Counts Within the Southern Peripheral Portion of the Sea Otter's Range Between Point San Luis and Oso Flaco Creek.

Date	Count	Date	Count
2- 8-79	22	1-21-80	100
2-14-79	44	1-30-80	100
2-26-79	64	2-13-80	103
3- 5-79	68	3-11-80	102
3-14-79	78	3-17-80	96
3-21-79	77	4- 4-80	102
4- 3-79	72	5- 8-80	134
5- 7-79	83	5-28-80	87
6- 6-79	51	7- 8-80	35
7-10-79	49	8- 4-80	19
7-27-79	51	9-15-80	24
8-10-79	28	10-24-80	28
8-21-79	41	12-16-80	22
9-26-79	42	2- 2-81	59
10-22-79	43	4- 1-81	43
11-14-79	54	6-16-81	30
12- 4-79	46	9-16-81	2