# A REPORT ON THE SEA OTTER, *ENHYDRA LUTRIS* L., IN CALIFORNIA


by

Paul W. Wild

and

Jack A. Ames

MARINE RESOURCES
TECHNICAL REPORT NO. 20

1974

CALIFORNIA DEPARTMENT OF FISH AND GAME
MARINE RESOURCES TECHNICAL REPORTS

**********

Marine Resources Technical Reports are research documents by Department personnel that are of sufficient importance to be preserved, but which for some reason are not appropriate for primary scientific publication. No restriction is placed on subject matter.

These Reports may be cited in publication, but care should be taken to indicate their manuscript status. The material in these Reports may eventually appear in the primary scientific literature.

Inquiries concerning the reports should be directed to the Editor, Robson A. Collins, Marine Resources Region, 350 Golden Shore, Long Beach, California 90802.

# A REPORT ON THE SEA OTTER, *ENHYDRA LUTRIS* L., IN CALIFORNIA

by

PAUL W. WILD and JACK A. AMES
Marine Resources Region

MARINE RESOURCES TECHNICAL REPORT NO. 20
California Department of Fish and Game
-1974-

## ABSTRACT

This report discusses in detail findings and observations of 5 years of research on the sea otter population and its relationship to the nearshore marine environment in California. Initial efforts were directed at providing some relief to the commercial abalone fishery in the Cambria - Point Estero area north of Morro Bay. This fishery has subsequently collapsed along with other commercial and sport abalone and sport crab fisheries throughout the sea otter's range due to continued sea otter foraging. Capturing, tagging and translocation studies, censusing studies, examination of sea otter remains, habitat surveys, food habits observations and studies on otters in captivity provide a broad base of information on the expanding sea otter population in California and its effects on resources utilized by man. Recommendations for sea otter management consistent with esthetic, recreational, and commercial uses of marine resources are included in this report.

CONTENTS

ACKNOWLEDGMENTS

We wish to extend our thanks to a large number of persons, both inside and outside the Department, whose assistance has made various phases of the research possible.

Many Department colleagues have contributed to this work. Melvyn Odemar, the initial project leader, and his assistant, Kenneth Wilson, provided the early direction for the research. Wilson provided continuity to research activities in an interim period when Odemar left the project in July 1970 and the senior author took over in October 1970. Wilson originated the idea for the diver-held sea otter capture device. When he was promoted to the Department's new kelp restoration project in May 1972, the junior author transferred to the project. Both Odemar and Wilson continued to be sources of advice and information. The intensive series of aerial censuses was made possible through the skill of the Department's Warden-Pilots, Leo Singer and Robert Powers. Singer served as pilot on most of the censuses while Powers was pilot on three early flights. Assisting with aerial censusing on three separate occasions were Reinhold Banek, Russell Goodrich and Daniel Miller. Glen Bickford, Earl Ebert and Dennis Judson assisted Odemar and Wilson with early trapping, tagging and translocation activities. Departmental divers who assisted with various phases of the diver-held capture device operations were: Earl Ebert, Daniel Gotshall, James Hardwick, Robert Hardy, Randolph Kelly, Robert Lea, Melvyn Odemar, Steven Schultz, Clifford Willis and Kenneth Wilson. Information from Point Estero diving surveys was provided by Richard Burge and Earl Ebert. Ebert's knowledge of sea otter food habits and effects of otters on resources used by man has been a valuable source of information. Field observations of sea otter behavior and food habits were conducted by Dennis Judson, Susan Summers and Lawrence Wade. Frank Hubbard and John McKenzie helped with public information aspects of the project which have been considerable. Jack Linn coordinated pesticide testing of sea otter tissues and Stanley Katkansky and Ronald Warner ran some pathological tissue examinations. Doyle Gates and Harold Orcutt maintained close contact with the project and offered encouragement and many helpful suggestions. Nancy Durell typed the manuscript.

A considerable amount of help was provided from outside the Department. Much early assistance with observations of translocated otters and other field work by several observers was coordinated by the late Richard Peterson of the University of California, Santa Cruz, under a grant from the Owings Foundation. Assisting with the necropsy program and processing of remains were Richard Hubbard, Biological Sonar Laboratory, Fremont; Aryan Roest, California State Polytechnic University; G. Victor Morejohn and David Lewis, Moss Landing Marine Laboratories (MLML); and James Mattison, Salinas surgeon. Additional consultation on necropsies was provided by L. D. Howard, retired surgeon, and Peter Morse, Gerald Petkus, and Thomas Williams, veterinarians. Examination of tissues for environmental contaminants was conducted by John Martin, MLML, Philip Murphy and James Rote of Hopkins Marine Station, and Stanton Shaw, formerly of HMS. Richard Hubbard coordinated initial captive sea otter studies at the Biological

Sonar Laboratory. Various personnel at Sea World, San Diego, assisted with capturing, transporting and maintenance of otters at Sea World for additional captive studies, particularly John Sweeney and Peter Schroeder, veterinarians, and James Antrim, head keeper.

To all of the above and those not mentioned, we extend our grateful appreciation.

PAUL W. WILD
JACK A. AMES

## FOREWORD

The Department of Fish and Game Sea Otter Research Project was initiated in July 1968 in response to recommendations in a report presented to the Legislature in January 1968. The report, requested by Senate Concurrent Resolution No. 74, 1967 Legislative Session, was entitled "Report on the Sea Otter, Abalone and Kelp Resources in San Luis Obispo and Monterey Counties and Proposals for Reducing the Conflict Between the Commercial Abalone Industry and the Sea Otter (Bissell and Hubbard, 1968)." The report established the guidelines and direction for the Sea Otter Research Project. A two-phase approach was recommended consisting of an initial three-year-phase to gather information necessary for confident, safe management of the sea otter and to provide a measure of relief to the commercial abalone fishery; and a subsequent continuing phase based largely on information gained during the first phase.

The project was staffed with two marine biologists, an Associate Marine Biologist as project leader and an Assistant Marine Biologist. Approximately 4 to 6 man-months of temporary help per year also were provided.

In the interim, federal legislation, resulting in the Marine Mammals Protection Act of 1972, has placed sea otters under the jurisdiction of the U. S. Department of Interior. This federal legislation precluded the state from implementing management of sea otters and trapping and tagging operations in progress were terminated on December 21, 1972, the effective date of the Marine Mammals Protection Act. Implementation of a management plan for sea otters and continuation of research now depends on obtaining a permit from the Department of Interior.

This report contains results of the project's research activities and management recommendations for sea otters consistent with beneficial uses of living marine resources.

## INTRODUCTION

The California sea otter pelt trade and subsequent over-exploitation of sea otters dates back at least to 1786 under Spanish rule and soon included fur traders of many nationalities. Due to extensive unregulated harvesting, sea otter populations declined to low levels throughout their range by the mid 1800's and the species was nearly extinct in California at the turn of the Twentieth Century.

Protection was provided sea otters by the International Fur Seal Treaty of 1911 which prohibited the taking of sea otters and fur seals. California laws prohibiting taking or possessing sea otters or their skins have been in effect since 1913. As further protection against shooting, the California Sea Otter Game Refuge was established in 1941; possession of firearms is prohibited within the Refuge. Initially the Refuge included the portions of Monterey County lying west of Highway 1 between Malpaso Creek and Swiss Canyon Arroyo and between Castro Canyon and Dolan Creek (Figure 1). In 1959 the Sea Otter Game Refuge was expanded to include all that land lying west of Highway 1 between the Carmel River on the north and Santa Rosa Creek at Cambria on the south.

With full protection, the sea otter population in California has made a remarkable recovery. From a remnant of a few animals in the vicinity of Point Sur at the turn of the century, the sea otter population has increased to an estimated 1,600 to 1,800 animals in 1973. During this time sea otters have extended their range from a small area along the Big Sur coast both to the north and south. Based on recent observations, the population now ranges from the vicinity of Santa Cruz, Santa Cruz County, to the vicinity of Point Buchon, San Luis Obispo County (Figure 2).

As sea otters increased in numbers and extended their range, a resource conflict developed between abalone fishermen and the sea otter in the commercial abalone beds from Cape San Martin to Cayucos. Examination of sport and commercial abalone catch records and fishery history in context with the sea otter's expanding range documents this conflict (Appendix I). The result has been that extensive sport and commercial abalone fisheries and sport rock crab fisheries have virtually disappeared in the wake of the expanding sea otter population. Concern over these and other mounting problems prompted the Department of Fish and Game's research on the sea otter population and related problems.

In this report, we have attempted to provide information on the sea otter population and present and potential resource use problems as well as to provide the basis for a rational solution to these problems which will assure the continuation of a healthy sea otter population along the California coast.

## RESEARCH ACTIVITIES AND RESULTS

The Sea Otter Research Project has used the recommendations made in the report to the 1968 Legislature as guidelines for the project (see

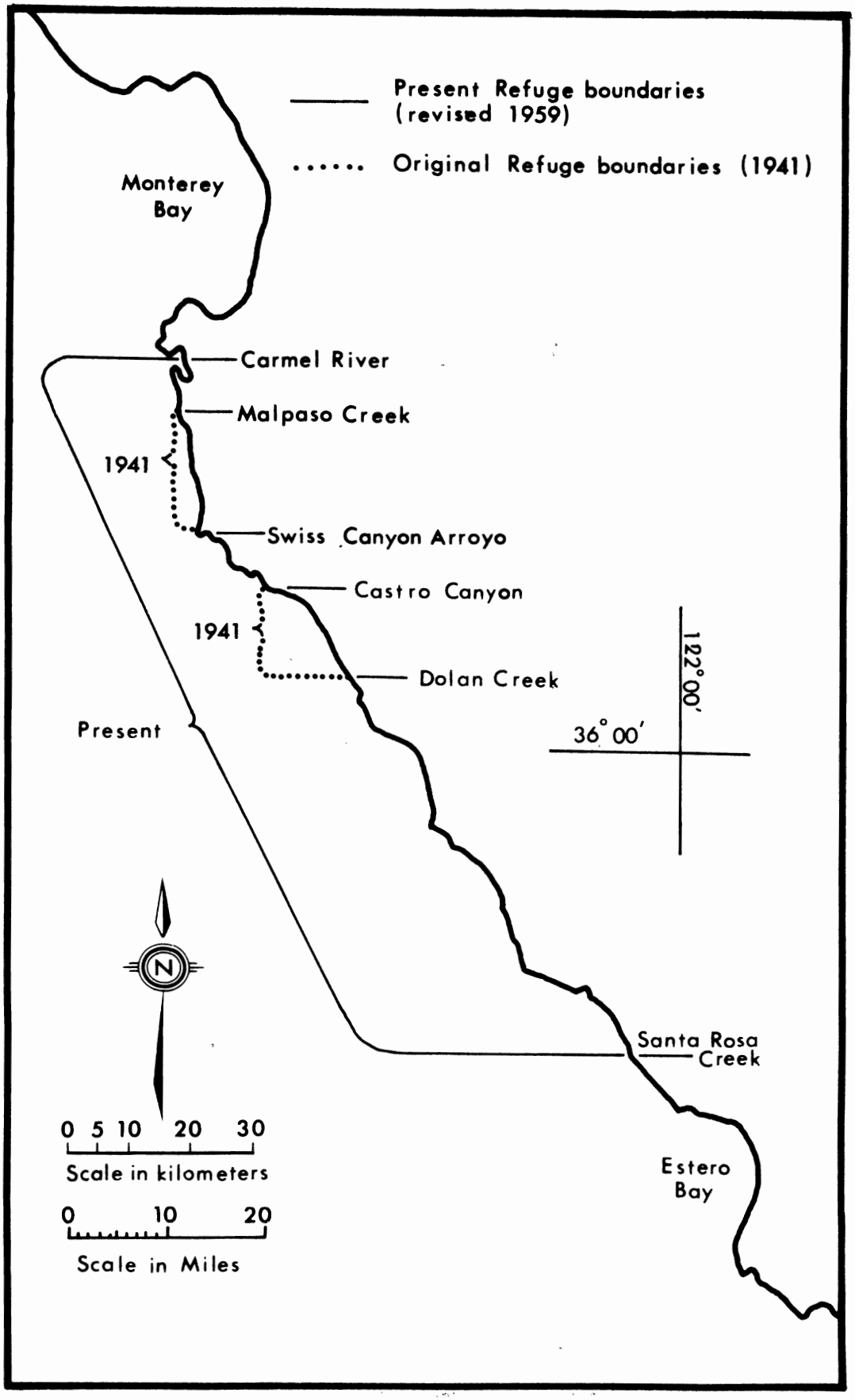


FIGURE 1. Original and present shoreline areas within Sea Otter Game Refuge boundaries.

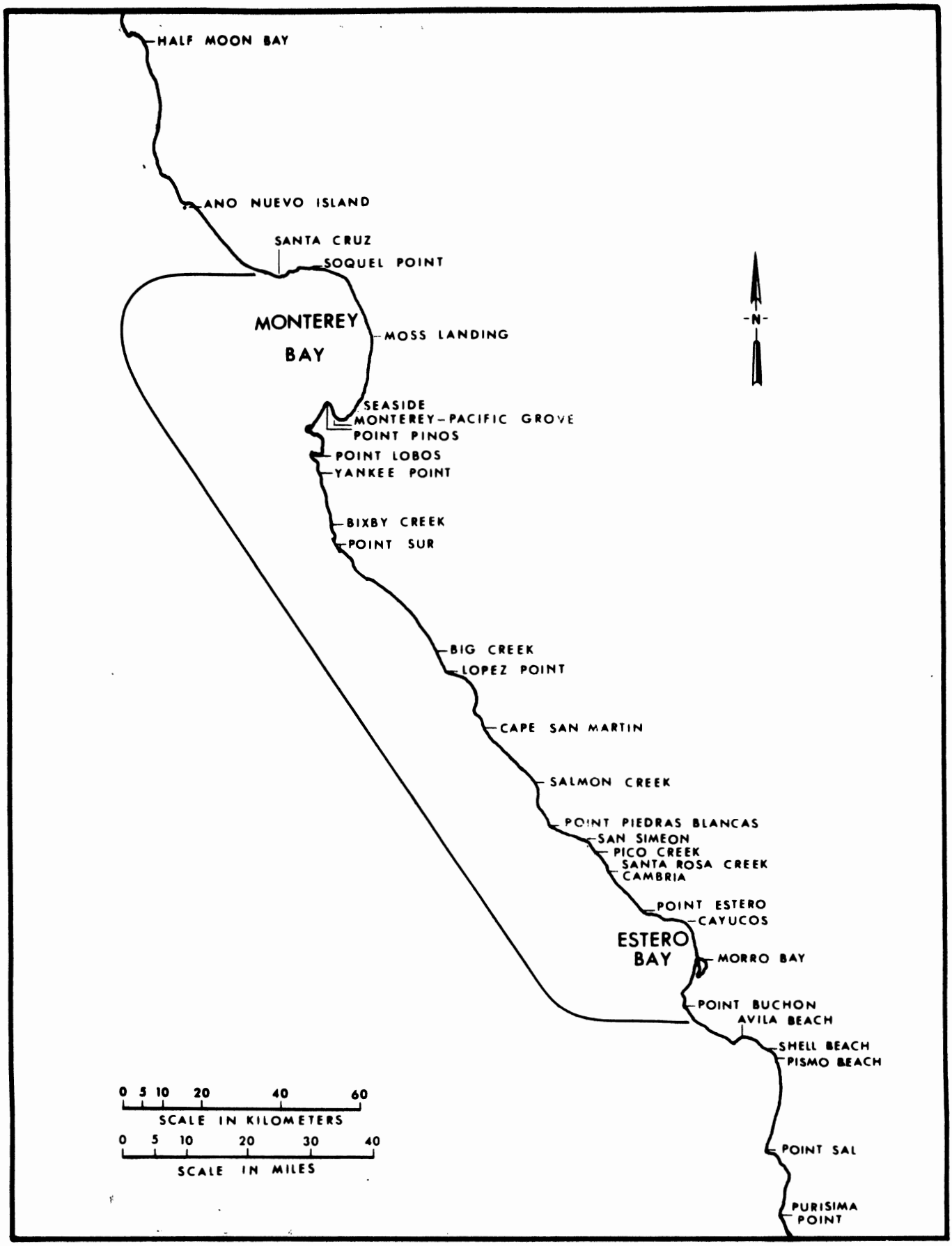


FIGURE 2. Range of the sea otter population along the California coast in mid-1973.

Foreword).

Based on observations of 15 to 30 sea otters in the northern portion of the Cambria-Point Estero abalone beds in 1967, it was recommended that 20 otters be translocated from this area and studied initially, in an attempt to provide some relief to the commercial abalone fishery still operating there. Additional animals could be removed if the Department was confident these operations would not endanger the species.

The following actions were recommended to implement the program:[1/]

1. Determine when the sea otters should be trapped and moved.

2. Begin ecological and environmental studies to determine areas to which otters might be relocated.

3. Trap, tag, and transport a limited number of sea otters. Develop skills in trapping, tagging and transporting. Gather biological information from animals trapped.

4. Investigate use of sonic tags in otter studies.

5. Experiment with effectiveness of underwater sounds to control otter movements.

6. Begin population dynamics study of the sea otter.

7. Develop a program to provide carcasses of dead otters found on the shore to scientific institutions for additional study.

8. Conduct underwater ecological and habitat studies in areas of actual or potential sea otter-abalone conflicts.

9. Make available up to six live otters to scientific institutions for study.

Sea Otter Research Project activities directed toward accomplishing these recommendations are presented in the following sections.

## Capturing, Tagging and Translocation Studies

It was decided that trapping and moving sea otters should begin as soon as adequate equipment was developed to conduct these operations. Therefore, the project's initial studies were directed toward developing safe, efficient techniques to capture, handle and translocate sea otters and to gather biological information from the animals trapped.

---

[1/] The order of these recommendations as they appeared in Bissell and Hubbard (1968) has been changed slightly to coincide more nearly with their discussion in this report.

Gear Development

Capture gear. The Department's concern for the welfare of California's sea otters provided the basis for developing the safest, most efficient methods for the capturing and handling of sea otters. At the inception of the program the project leader, then Melvyn Odemar, was sent to Amchitka Island, Alaska, to observe the capture and handling techniques being employed by the Alaska Department of Fish and Game in their sea otter transplanting program.

Our trapping operations were initiated in early January 1969. Initial capture techniques, similar to those employed in Alaska, utilized floating, unweighted gill nets to entangle swimming sea otters. The animals were subsequently removed from the nets and placed in specially designed cages when translocation was being accomplished (Odemar and Wilson, 1969c). In all, 17 sea otters were translocated within the range from Cambria to Big Creek in 1969. In addition, some animals were tagged and released on site.

During 1969 and 1970, a total of 29 sea otters was captured utilizing the floating gill nets. Of the 29, 5 (17%) died of causes that could be directly attributed to capture or translocation activities. Since any capturing program would only involve a fraction of the total population, it is doubtful that this level of capture mortality would have any adverse biological effects on California's sea otter population. Nevertheless, trapping was delayed while investigations continued to develop techniques to reduce such mortalities. We developed and tested a floating, baited sea otter cage and an over-the-kelp net. Although these devices could reduce mortality significantly, field experiments indicated that they were not effective for capturing sea otters.

Subsequently, a diver-held sea otter trap was devised (Figure 3). A series of gear trials culminating in the capture of one sea otter indicated that this device would provide a safe method for capturing sea otters in areas where animals may be approached easily. These trials also indicated that this gear would eliminate drowning of otters where its use is applicable. The device also reduces the amount of stress to which an animal is submitted because handling is kept to a minimum.

In late November 1972 capturing and tagging operations with the diver-held trap were initiated. By December 21, 1972, 28 sea otters had been captured with the new device. No sea otter mortality occurred during the capturing operations. The primary cause of death which was drowning in the nets is eliminated with the diver-held device. Of the total, 23 were tagged and released on site and 5 were transported to Sea World, San Diego, for special scientific studies. The fur of one of these animals, a male, became soiled during transport and the animal became wet to the skin when released into the pool at Sea World and died of exposure within a week.

Capturing operations were terminated on December 21, 1972, to conform to the federal Marine Mammals Protection Act, which became effective on

FIGURE 3. The diver-held sea otter trap is maneuvered beneath a sea otter rafting in kelp. Upon encountering the otter from below, the drawstring is pulled, thereby closing the net and trapping the otter. $CO_2$ inflatable floats (uninflated in picture) help to support the device at the surface while the boat arrives. Photograph by Paul W. Wild.

that date. Any further research on sea otters which involves handling the animals will now require a permit from the U. S. Department of Interior.

Tagging gear. Three sea otters captured during the initial gill netting operations were transported to Stanford Research Institute's Biological Sonar Laboratory, where tagging experiments were undertaken to find tags that were permanent, easily visible from a distance and non-injurious to the animals. The most satisfactory tags were found to be anodized aluminum cattle ear tags. They are attached with special pliers through the webbing of the otters' hind feet and can be coded by color, shape and number. Sex of the tagged animals is designated by placement of tags on the right for males and the left for females (Figure 4).

The use of sonic tags to facilitate observations of movement patterns of sea otters was investigated during our tagging studies. Such devices were considered unworkable because of difficulties involved in attaching the tags without harming the otters and preventing damage to the delicate sonic transmitting equipment by the animals.

Estes and Smith (1973) recently experimented with radio telemetry collars on sea otters at Amchitka with encouraging results on animals in captivity. However, when animals were released with radio transmitters, none could be located after a maximum of 3 days. It was thought that the radios may have been damaged by otters crawling about on rocky shores or from being chewed upon.

Further attempts should be made to locate a safe, effective, otter-proof tracking device to aid in field studies.

## Summary of Capture and Disposition of Sea Otters

### Gill Net Operations.

1969

17 male sea otters captured at Cambria were translocated to Big Creek.

3 male sea otters captured at Cambria were transferred to the Biological Sonar Laboratory, Fremont, California. One died a week later. The other two lived nearly 8 months in captivity.

3 sea otters (one female, two males) drowned during netting operations at Cambria.

(Thus, 23 sea otters were removed from the Cambria-Point Estero area.)

3 male sea otters were captured, tagged and released at Cambria.

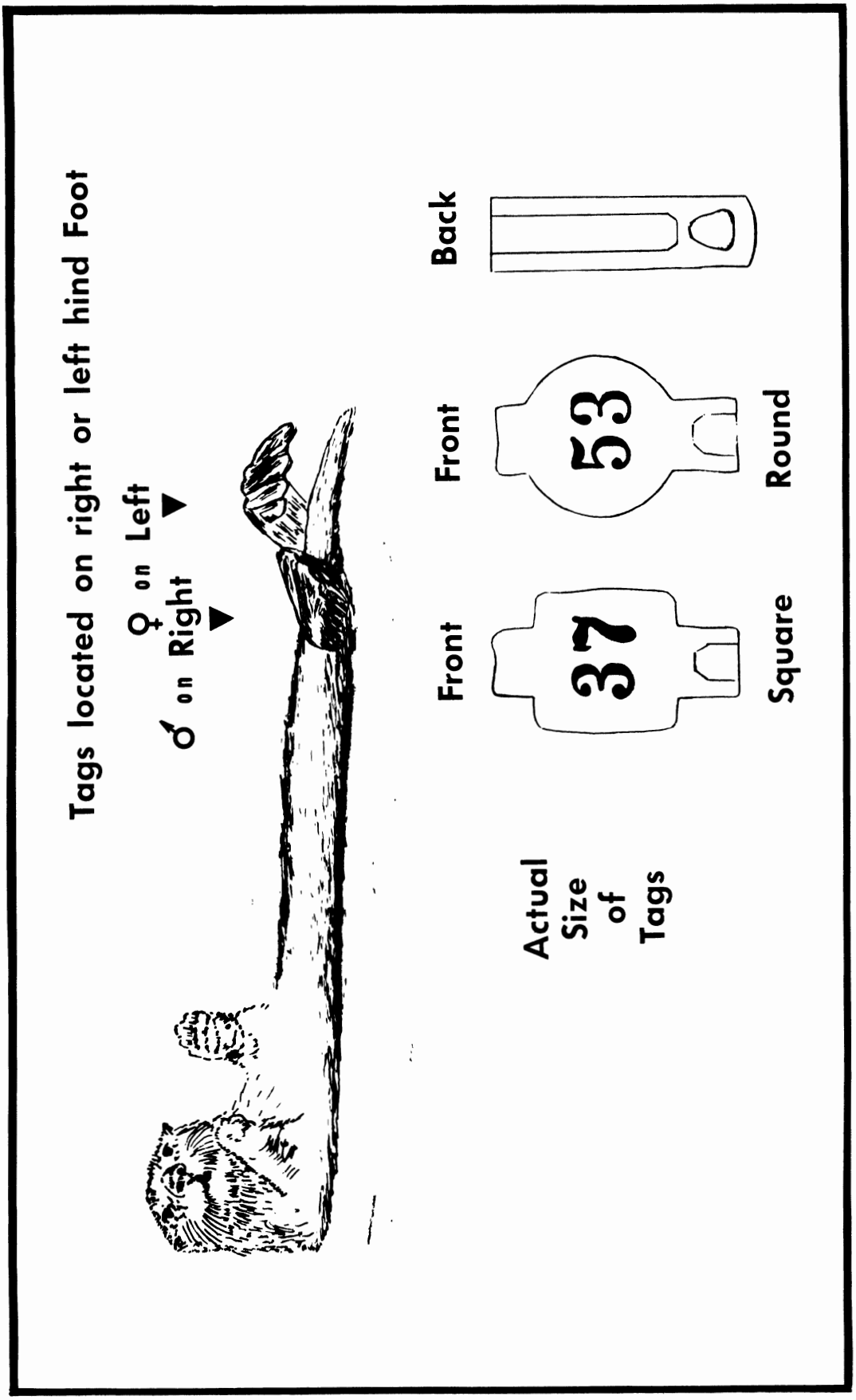


FIGURE 4. Tags used on sea otters.

1970

2 sea otters (one male, one female) were captured, tagged and released at Monterey.

1 female sea otter drowned during capture at Monterey.

Diver-held Capture Device Operations.

1971

1 male sea otter was captured, tagged and released at Monterey during gear trials with the diver-held capture device.

1972

6 male sea otters captured, tagged and released at Cayucos Point.

6 male sea otters captured, tagged and released just north of Point Estero.

3 female sea otters captured, tagged and released in the vicinity of Cambria.

1 male sea otter captured, tagged and released off Cannery Row, Monterey.

7 female sea otters captured, tagged and released off Del Monte Beach, Monterey.

5 sea otters (2 males, 3 females) captured in vicinity of Monterey (males off Cannery Row, females off Del Monte Beach) and transported to Sea World, San Diego. One male died within a week. The other 4 have adapted well to captivity.

58 Total

Translocation within the Range

Translocation within the sea otter's range was accomplished during January, April, July, and August 1969. During this period, a total of 17 sea otters was translocated from the Cambria area to Big Creek, approximately 72 km (45 miles) to the north, in an attempt to provide a measure of relief to the commercial abalone fishery.

It is of interest, however, that on November 8, 1968, 62 sea otters had been observed in the Cambria-Point Estero area (Wilson, 1968b) and on March 10, 1969, after translocation activities had begun, 129 sea otters were observed in the area (Wilson, 1969a). In addition, some of the otters which were translocated were subsequently observed back in the area.

The first evidence that otters would return to the area of capture was the sighting of a translocated otter off Cambria on September 25, 1969 (Odemar and Wilson, 1969c). On October 12, 1969, four tagged otters released at Big Creek were sighted about 6 km (4 miles) south of Cambria off the Cambria Air Force Radar Station. Thus, five are known to have returned about 72 km (45 miles) by water to where they had been captured. In all probability, more otters returned than the approximately 30% that were sighted. The carcasses of two otters tagged and released at Big Creek in April and August of 1969 were recovered near Cambria in March and June of 1970, both nearly 11 months after release. Both carcasses were so badly decomposed when recovered that it was impossible to determine cause of death. Whether or not these carcasses were those of tagged otters spotted in September and October of 1969 or the carcasses of different animals cannot be determined as tag numbers were not obtained during the original sightings. These sightings and recoveries indicate that translocation across continuous rocky reef - kelp bed habitat is not an effective means of distributing sea otters within their range to control range expansion. Whether translocated otters will return across long expanses of sandy habitat as readily has not been determined by these experiments.

In 1972, 277 sea otters were observed between Cambria and Cayucos. Subsequently, sea otters have extended their range south of Morro Bay, where as many as 137 were observed off Point Buchon in April 1973. Thus, the characteristics of the expanding sea otter population precluded providing any relief to the commercial abalone fishery and the divers abandoned the abalone beds north of Morro Bay in 1971.

Survey for Extralimital Translocation Sites

Translocation of sea otters outside the present range was suggested as a method of providing relief to the Morro Bay based abalone fishery. In addition, the successful establishment of discrete sea otter populations would minimize the extent of damage that a disaster such as an oil spill could cause to California's sea otter resource.

A habitat survey of prospective sea otter translocation sites outside the present range was conducted to locate habitat suitable for sea otters without a high potential for resource conflicts.

The California coastline and offshore islands south of Avila were not considered to be suitable for the translocation of sea otters because of the extreme potential for resource conflicts with existing sport and commercial abalone, lobster, and crab fisheries.

Historical records indicate that the nearshore waters along much of northern California's rugged coast provided suitable habitat for considerable numbers of sea otters. Two aerial habitat reconnaissance surveys were conducted north of the sea otter's range to the California-Oregon border in August and November 1969. These flights were followed by a shore survey of the Marin County coastline from Point Bonita to Point

Reyes. Information gathered from these surveys included suitability and extent of potential habitat, accessibility and public usage. Maps and aerial photographs were examined and people familiar with the areas were consulted regarding suitability of possible transplant sites. Examination of resource use data from the areas surveyed reveals that large scale commercial fisheries for crabs, oyster farming, and important sport fisheries for abalones, clams and scallops occur in these areas. The establishment of sea otter populations in the same areas would result in conflicts for the use of these resources.

Results of these surveys and conferences indicated that none of the sites in northern California suitable for translocation of sea otters would be free from potential conflict with existing resource usage.

## Consideration of Sonic Barriers

The possibility of developing effective sonic methods to limit sea otter movements was discussed at length at a meeting on the Sea Otter - Abalone controversy in October 1969 (Donald L. Grunsky, California State Senate, transcript of conference on Sea Otter - Abalone Controversy, Moss Landing Marine Laboratories, October 2, 1969). A number of experts contributed information at the meeting: Karl Kenyon, U. S. Fish and Wildlife Service, sea otter research; G. Victor Morejohn, Moss Landing Marine Laboratories, marine mammals expert; Melvyn Odemar, California Department of Fish and Game, sea otter research; Thomas C. Poulter, Biological Sonar Laboratory, marine mammals expert; and John Vania, Alaska Department of Fish and Game, sea otter research.

The concensus of these authorities was that studies to develop sonic barriers to limit sea otter movements would be costly and would most likely prove futile in light of existing knowledge of sea otter behavior. Consequently, the subject of sonic barriers has not been given further consideration by the project.

## Population Dynamics

An adequate knowledge of sea otter population dynamics is needed to understand the characteristics of continued population and range expansion, to predict future population trends and to evaluate the effects of sea otters on the nearshore environment. These data are also essential for making management recommendations for sea otters. Information which is needed includes total population estimates and distribution, sex ratios and age groupings throughout the range and fluctuations in numbers and range expansion. Some of these data have been obtained in the course of censusing, capturing and tagging operations for translocation, behavioral and physiological studies and from recovery of carcasses found along the shore. However, much remains to be learned.

Information from censusing and capturing and tagging operations is discussed in this section while information from carcass recoveries is included in the following section on Examination of Sea Otter Remains.

## Censusing Studies

Bissell and Hubbard (1968) compiled records of counts and observations of sea otters along the California coast from 1911 to 1967. These records confirm that at least a few sea otters persisted along the California coast prior to 1938 (Bryant, 1915; Farnsworth, 1917; Oyer, 1917). After a "rediscovery" of sea otters in 1938, there were reports of up to 150 in the Point Sur area (Bolin, 1938). A census by helicopter in 1957 produced a total count of 635 sea otters between Carmel Bay and San Simeon and an additional 3 were reported at Point Conception (Boolootian, 1961). A series of Departmental censuses by plane from 1964 to 1967 varied from 137 to 591 sea otters and indicated that the population ranged from Monterey to Cambria by 1967 (Carlisle, 1966a, b; 1967a, b). It was thought that the population had stabilized or even declined at that time.

In August 1968, the Sea Otter Project began an intensive series of aerial censuses throughout the sea otter's range to estimate population size, document range expansion, and determine distribution patterns. At times aerial counts were coordinated with observers on shore and in boats. Localized censuses were made at other times to provide supplemental data.

Initially our aerial censuses were conducted from a Departmental Cessna 180. Since March 1969, a Departmental twin engine Cessna Super Skymaster has been used. Personnel generally included a pilot and two biologist-observers. A flight pattern was developed in which from one to several passes were made over a given section of coast depending upon the configuration of the shoreline and extent of existing kelp beds. Altitudes flown ranged from about 15 to 168 m (50 to 550 ft), depending on nearby terrain and flying conditions. The optimal observing and counting altitude was about 30 m (100 ft). Minimum air speed was about 161 kph (100 mph). One observer sat in the co-pilot's seat; the other sat behind the pilot. Each observer counted only the otters observed on his side of the plane. The pilot was helpful in locating and verifying counts of otters. When a large group of sea otters (approximately 25 to 50 or more) was located, the plane was circled at a pivotal altitude of about 174 to 183 m (570 to 600 ft) over the group while the observers counted the group of otters independently. The independent group counts were then averaged. Counts of sea otters were recorded by number and location on topographic maps and were totaled later. Conventional and infra-red photography have not proven useful, so we have relied on direct counts.

Initially, the entire survey area was covered in one day. However, since May 1970, in an attempt to reduce observer fatigue, census flights have been conducted over two consecutive days by terminating each day's censusing just south of Point Sur, an area which has been consistently characterized by a low density of animals.

Aerial censuses were usually made during the hours from 0800 to 1500 because more sea otters tend to be concentrated in groups from mid-morning to early afternoon. This general period of resting or sleeping has been documented by several observers (Kenyon, 1969; Peterson and Odemar, 1969; and Estes and Smith, 1973).

From August 1968 to April 1972, 21 aerial censuses were conducted by the project (Odemar, 1969; Odemar and Wilson, 1969a; Wild, 1971; Wilson, 1968a, b, 1969a, b, c, d, e, f, 1970, 1971a, b, c, 1972a, b; Wilson and Odemar, 1968, 1969, 1970). Complete coverage of the range was precluded by intermittent fog on three occasions. On another flight, only selected areas were censused to test photographic techniques. The remaining counts were obtained during observing conditions which varied from poor to excellent and ranged from 377 to 1,060 sea otters. Seven of the counts have exceeded 9 hundred animals.

Counts obtained since May 1970 have averaged higher than our previous counts. This is probably due in part to improved censusing techniques, but also indicates an increase in the population which is resulting in further range expansion. These censuses reveal that the population has not stabilized, but has continued to increase both in numbers and range. The highest counts do not represent the total population which, at best, can only be estimated.

Population Estimates

Only infrequent observations of a few sea otters in scattered locations were made along the California coast in the early 1900's, making it difficult to estimate the numbers which remained after protection was provided. The population which existed near Point Sur in 1938 subsequently has been estimated at as much as 3 hundred (Boolootian, 1961). Bissell and Hubbard (1968) report that the sea otter population in 1948 was estimated to be 5 hundred animals and in 1967 nearly 7 hundred. No computational basis is given for any of these estimates.

Population estimates of sea otters in California have generally been developed from shore or aerial counts which have not always been too reliable due to variable censusing conditions. Since both aerial and surface counts of sea otters are affected widely by weather and sea conditions and extent and kind of kelp beds present, it is of value to have a reliable method for making population estimates from counts obtained during a variety of observing conditions. The data from our aerial counts along with surface counts, an indication of censusing conditions from flight reports, and a general knowledge of sea otter behavior provide a basis for developing such a method.

Shore counts have generally been higher than aerial counts, particularly in central and southern portions of the range. One of the reasons is that ground crews may spend several hours in an area the plane covers in a half hour. Thus, aerial observers are more apt to miss diving animals,

scattered individuals, or even a group occasionally. In addition, it is difficult to discern pups closely associated with their mothers. A female sea otter characteristically carries its pup on her chest and abdomen while floating on her back, making it difficult to spot pups from the plane.

Corresponding surface counts in three separate areas during aerial censuses in 1969 (5 corresponding counts in 2 areas and 9 in the third) averaged 97, 129 and 159% of aerial counts (Odemar and Wilson, 1969b). We averaged these three percentages to obtain an approximate figure to apply to total aerial counts. Thus (using a figure of 128%, shore to aerial count), if 1,000 sea otters were observed during an aerial census, we would expect shore observers, if it were possible to census the entire range from shore, to count on the average 1,280 sea otters. It is also very unlikely that shore observers will be able to count all the otters in a given area. If we assume a conservative shore census error of 3 to 5% during ideal conditions, then by increasing the estimated shore count of 1,280 by 4% the total number of otters in the area would be 1,331. Therefore, we can assume that an aerial census of 1,000 sea otters under excellent conditons, on the average, counts 75% of all the animals in the population ($\frac{1,000}{1,331} = .75$). Using this as a basis, a sliding scale can be developed to produce total population estimates from all counts which cover the entire range by adjusting for less than ideal observing conditions (Table 1). Admittedly, the evaluation of observing conditions is somewhat subjective, especially since no attempt was made to standardize recording of such conditions on our flights. However, we had three other persons independently evaluate census conditions from the flight reports and results, in a majority of the cases, were remarkably consistent with ours. Therefore, by averaging our population estimates on an annual basis, we estimate the total California sea otter population in 1969, 1970, 1971, and 1972, at approximately 1,300, 1,400, 1,530, and 1,650, respectively. Furthermore, since further range expansion by significant numbers of sea otters occurred in early 1973 (see section on Range Expansion), we estimate the present population to be between 1,600 and 1,800 animals.

The data in Table 1 also indicate that some earlier estimates of the sea otter population were conservative. For example, it is extremely unlikely that the present rate of population increase would have allowed the 700 estimated sea otters in 1967 (Bissell and Hubbard, 1968) to increase to the January 1969 count of 983, let alone our estimate of 1,311 (Table 1) at that time.

Range Expansion

The re-establishment and growth of a significant sea otter population from a small group in the Point Sur area in the early 1900's has resulted in the spread of the population both to the north and south along the central California coast (Figure 5). In 1938, the population was reported at Bixby Creek (about 4 miles north of Point Sur) and in the general vicinity south of there (Bolin, 1938). The range probably did not extend far south of Point Sur then, since the northernmost and southernmost Sea Otter Game Refuge boundaries established in 1941 (Figure 1)

TABLE 1. Aerial Counts, Censusing Conditions and Population Estimates of Sea Otters in California from August 1968 through April 1972.

| DATE | AERIAL COUNT | CONDITIONS1/ | ADJUSTMENT2/ FACTOR | POPULATION ESTIMATE |
|---|---|---|---|---|
| Nov 8, 1968 | 664 | Good | 65% | 1022 |
| Dec 20, 1968 | 377 | Poor | 30% | 1257 |
| Jan 31, 1969 | 983 | Excellent | 75% | 1311 |
| Feb 10, 1969 | 770 | Good - Poor3/ | 60% | 1283 |
| Mar 10, 1969 | 931 | Very good | 70% | 1330 |
| Jun 2, 1969 | 1014 | Excellent | 75% | 1352 |
| Aug 1, 1969 | 529 | Fair - Poor | 45% | 1176 |
| Oct 6, 1969 | 483 | Fair - Poor | 35% | 1380 |
| Dec 1, 1969 | 649 | Good - Poor | 50% | 1298 |
| May 6, 1970 | 1040 (314 + 726) | Excellent4/ | 75% | 1536 |
| May 7, 1970 | | Good | 65% | |
| Sep 16,17, 1970 | 612 5/ | Fair | 50% | 1224 |
| Feb 12,13, 1971 | 718 | Fair | 50% | 1436 |
| Apr 15,16, 1971 | 902 | Good - Fair | 60% | 1503 |
| Jun 30, 1971<br>Jul 1, 1971 | 959 | Good - Fair | 60% | 1598 |
| Oct 5,6, 1971 | 715 | Good - Poor | 45% | 1589 |
| Jan 4,5, 1972 | 1060 | Fair - Very Good | 65% | 1631 |
| Apr 19, 1972 | 770 (377 + 393) | Poor - Fair | 35% | 1682 |
| Apr 20, 1972 | | Good | 65% | |

1/Criteria for evaluating censusing conditions:
- Excellent - Minimal wind, high overcast (water glassy, no glare), reduced kelp canopy (especially bull kelp, *Nereocystis*).
- Good - Light winds, and overcast; or minimal wind, some sunglare present; moderate to light kelp canopy.
- Fair - Moderate winds and surface glare; or moderate to strong winds and some sun glare; moderate to dense kelp canopy.
- Poor - Strong winds, intense glare, dense kelp canopy (especially bull kelp, *Nereocystis*).

2/Indicates estimated percent of total population counted as follows:
- Excellent - 75%
- Good - 65%
- Fair - 50%
- Poor - 30%

3/Underline indicates adjustment factor was weighted toward underlined item.

4/When conditions were different on separate days of a census, they were rated separately.

5/One of the observers was inexperienced.

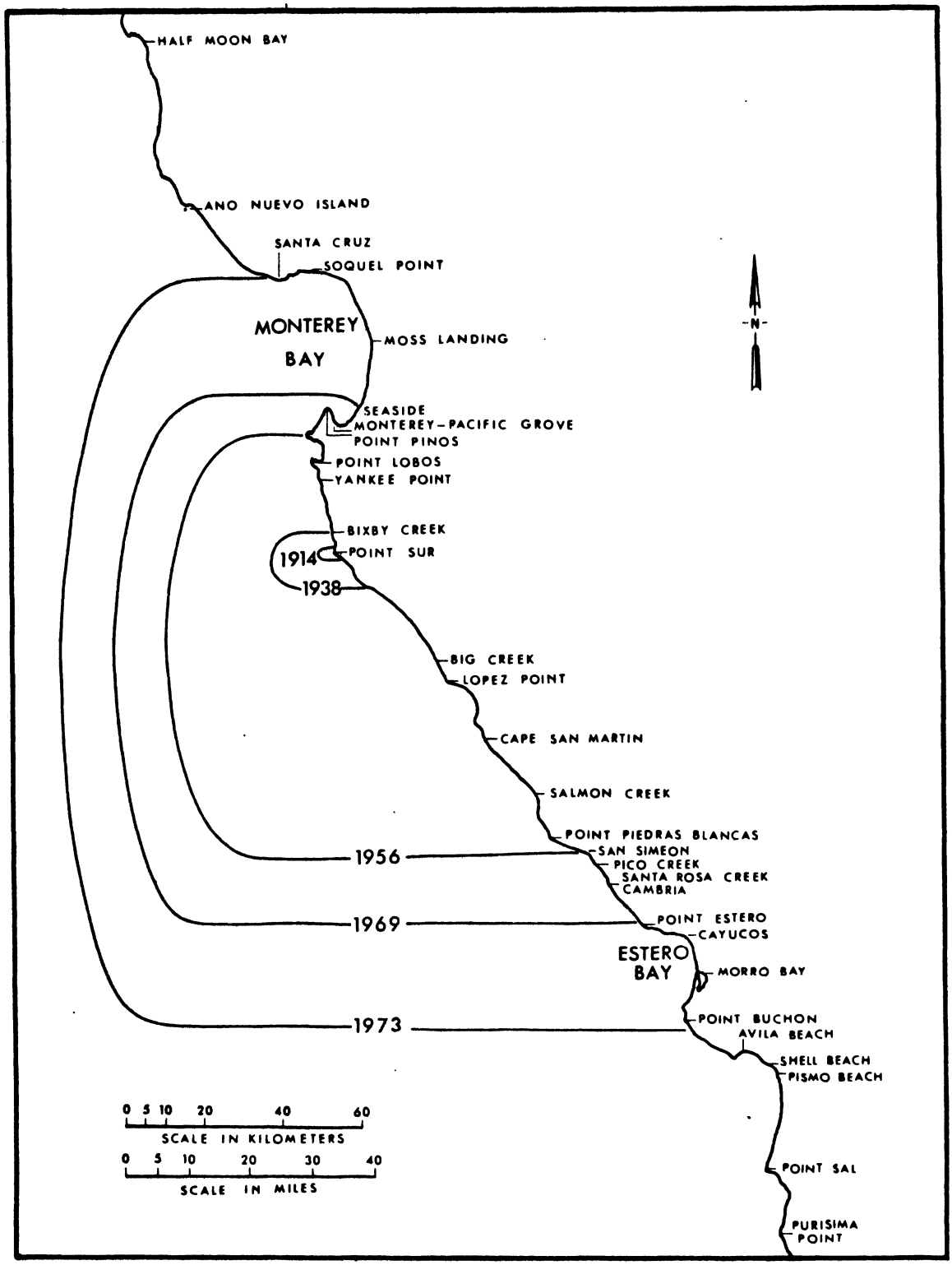


FIGURE 5. Range expansion of the sea otter population in California from 1914 to 1973.

probably encompassed all of the range at that time. During the 1940's and early 1950's some unpublished observations and counts from shore were made but the ruggedness and inaccessibility of much of the central coast made it difficult to obtain a clear picture of the established range and numbers of sea otters. The range apparently had extended to about Yankee Point on the north and the vicinity of Salmon Creek on the south by the early 1950's (Peterson and Odemar, 1969). The first aerial census of sea otters which was made from a helicopter in 1956 indicated that the established range was then from Carmel Bay to the vicinity of San Simeon (Boolootian, 1961). Boolootian considered the range to extend to Point Conception, near Santa Barbara, based on three sea otters he reportedly observed there. However, subsequent censuses and observations indicated that no established sea otter range occurred south of San Simeon at that time. Our censuses since 1968 indicate that the established range extended from Seaside to Point Estero by 1969 and from Santa Cruz to Point Buchon in early 1973.

Occasional observations of sea otters and carcass recoveries are made well beyond established range boundaries. These incidents do not represent range expansion since such occurrences are only temporary and established populations have not subsequently developed in these areas.

Several examples of such sightings have been published. Two sea otters were reported at San Miguel Island in 1954 (Allanson, 1955), two at Trinidad Head in northern California in 1956 (Bentley, 1959), and two at Ano Nuevo Island in 1963 (Orr and Poulter, 1964). In 1967, several sightings of a single otter were made within a month in southern California at Malibu Point, Santa Monica Bay and Santa Barbara (Bissell and Hubbard, 1968). All were possibly the same animal.

A commercial fisherman accurately described to one of the authors what he reported as a sea otter at Half Moon Bay, about 32 km (20 miles) south of San Francisco, on May 6, 1973.

Occasionally, unconfirmed reports of sea otters, particularly from the northern California coast, are received. Attempts to confirm these have all been futile and no populations are known to have developed in these areas.

Several sea otter carcasses have been recovered considerable distances beyond established range boundaries. The carcass of an adult female sea otter was recovered from the Santa Cruz area as early as 1940 (Orr and Poulter, 1964). In October 1970, the badly decomposed carcass of a mature male sea otter was recovered at Point Reyes about 56 km (35 miles) north of San Francisco. In April 1971, a badly decomposed sea otter carcass was found at San Miguel Island.

On July 22, 1970, a live male sea otter pup was brought to park rangers at U. S. National Seashore, Point Reyes. The animal, which reportedly had been found on a beach nearby, died at Steinhart Aquarium

the next day. It is extremely unlikely that this pup, which was obviously still dependent upon its mother, actually came ashore in this area since no sea otters are known to inhabit the area. Within their range, sea otter pups occasionally become separated from their mothers and become stranded on shore. This may have been a stranded pup which was picked up by someone within the current range and abandoned at Point Reyes soon thereafter.

Because of the occurrence of "wanderers" far beyond established range boundaries, it is of value to be able to delineate established sea otter range and to understand the characteristics of range expansion in order to evaluate the ecological relationships of sea otters to the nearshore marine environment. Intensive aerial and surface censusing and field observations in recent years provide some insight into the characteristics of sea otter range expansion.

Observations at the southern end of the range indicate that by late 1968 the population was established to the south end of Cambria where a rafting group[2/] of 40 to 50 sea otters was observed in November 1968. About 13 sea otters were scattered 5 to 6 km (3 to 4 miles) north and south of this rafting group. In December, a rafting group of about 25 sea otters plus 5 scattered individuals were observed about 6 km (4 miles) south of Cambria off the Cambria Air Force Radar Station. Throughout most of 1969, the southernmost rafting area remained off the Radar Station. A maximum of 115 sea otters was counted in the raft in this area in early 1969. Scattered individuals were usually observed 3 to 4 miles to the north and south of the rafting area.

No censuses were made in early 1970. However, in May 1970, an aerial census made during very good conditions revealed that the rafting area had shifted to the north where two groups of sea otters, one of at least 95 and another of 58, were observed off Cambria. No otters were observed from there to Cayucos Point, nearly 16 km (10 miles) south, where 9 were observed. This shift primarily to the north may have been due to a rash of sea otter shootings which apparently occurred in 1970 (see section on Examination of Sea Otter Remains). By September 1970, a rafting area had been re-established in the vicinity of the Cambria Air Force Radar Station although it was noted that the animals seemed to be more startled by the plane than usual.

During 1971, the southernmost rafting area remained off Cambria Air Force Radar Station where as many as 150 were observed in the raft in April. In late 1971 scattered individuals were more commonly seen to the south in the vicinity of Cayucos Point, where as many as seven were counted during the October flight. However, no rafting area had been established there yet.

---

[2/] Bunching or "podding" of sea otters usually occurs in kelp beds and has come to be termed "rafting". A raft of sea otters usually develops when sea otters rest or sleep in close association to one another in the kelp, each with a few fronds of kelp draped over its body.

In February 1972, observations from shore indicated that a rafting area had been established at Cayucos Point. During the April census, 74 sea otters (rafting groups and scattered individuals) were observed there. By December 1972, in a survey from shore, 207 sea otters were counted at Cayucos Point while only 70 in small groups and scattered individuals were observed then from Point Estero to Cambria in the vicinity of the former southernmost rafting area.

In January 1973, observations from shore confirmed that the population had expanded its range across 23 km (14 miles) of sandy habitat to the first rocky reef - kelp bed habitat south of Estero Bay; 137 sea otters were counted at Point Buchon in April.

Maximum counts in the Cambria to Cayucos area during 1968, 1969, 1970, 1971 and 1972 were 62, 129, 165, 187, and 277, respectively. The increasing numbers of sea otters in this area coincided with the overall shift of the southernmost rafting area to the south, which progressed from the movement of otters into the northern portion of the Cambria - Point Estero area in 1967 to occupation of the entire area by 1972 and the subsequent expansion of the range to Point Buchon in early 1973.

Range expansion at the northern end of the range, although similar to that which is occurring at the southern end of the range, has exhibited a slightly different pattern.

Before 1963, sea otters were rarely seen inside Monterey Bay. Inside the Bay, rocky reef - kelp bed habitat extends from Point Pinos at the south end of the bay to the Monterey Marina and continues where a shale reef supports a kelp bed off Del Monte Beach near Seaside. It is about 10 km (6 miles) from Point Pinos to Seaside. A long stretch of sandy beach and sandy offshore bottom habitat extends from Seaside to Soquel Point, a distance of about 48 km (30 miles) along the shoreline, where the next suitable sea otter habitat exists.

In 1963, sea otters moved around Point Pinos into Monterey Bay, where approximately 75 sea otters were seen a short distance inside the Point off Pacific Grove in April of that year (J. B. Phillips, pers. commun.).

In 1966, during Departmental aerial sportfishing surveys, sea otters still were being seen, in numbers, only a short distance inside Point Pinos, where the main rafting area was off Pacific Grove (Daniel Miller, pers. commun.). A maximum of 94 sea otters was observed by Miller in this area in March, but by November no otters were being observed inside Monterey Bay during these aerial surveys. However, by 1968 sea otters had established their range to Del Monte Beach in the vicinity of the Monterey-Seaside border, where a group of 25 was observed in this area of limited kelp bed habitat in late 1968. Varying numbers of sea otters were observed in the Seaside area during 1969 with a maximum of 30 sea otters observed there in February 1969. During 1970, 1971 and 1972 aerial counts in this area did not exceed 13 sea otters.

It appears that sea otters had not fully occupied the area from Point Pinos to Seaside by late 1968, when a maximum of 66 animals was counted in this area. The rafting area closest to the Seaside group at that time was off Lovers Point about half way between Point Pinos and the Monterey Marina. This rafting area was observed to shift along the shoreline to Monterey, where by late 1969 the rafting area was off Hopkins Marine Station at about the Pacific Grove - Monterey border. By early 1971, the rafting area had shifted to Monterey's Cannery Row, an area which has continued to be a popular spot for viewing considerable numbers of sea otters. Maximum annual aerial counts in the Point Pinos - Seaside area from 1969 to 1972 have been 159, 139, 170 and 120, respectively.

The numbers of sea otters off Cannery Row have fluctuated considerably, but a high of 110 (in rafting groups and individuals) was counted off Cannery Row in April 1971.

On February 5, 1973, we counted 45 sea otters off Seaside. If range expansion continues as we have observed it, we expect to see significant numbers of otters off Santa Cruz in the near future with lower densities remaining off the southern Monterey Bay shoreline.

Since 1969, nine sea otter carcasses (six adults, three subadults) have been recovered in the vicinity of Moss Landing at the center of Monterey Bay. One of these was drowned in a fishing net set in Elkhorn Slough near Moss Landing. The other carcasses could have drifted in or may have been animals in transit. It is not unusual now to see live sea otters in the area between Seaside and Santa Cruz.

Before 1970 it was unusual to see a sea otter on the Santa Cruz side of Monterey Bay. However, during the May and September census flights in 1970 (the only aerial censuses that year) a single otter was observed in this area on each flight. In 1971, three sea otters were seen on each of two flights and a single otter on a third flight. On one of the census flights in 1972 a single otter was seen in the Santa Cruz area. Nevertheless, it was apparent that the population had not yet become established there. On April 10, 1973, during a survey from a boat in the Santa Cruz area we counted five sea otters in the vicinity of Soquel Point and have received unconfirmed reports of at least eight sea otters in the Soquel Point - Santa Cruz area.

Although the 23 km (14 miles) of sandy habitat between Cayucos and Point Buchon did not appear to be any barrier to southward range expansion, the long stretch of sandy habitat in Monterey Bay from Seaside to Soquel Point appears to have delayed range expansion across the bay. Expansion of the population to this area now appears to be occurring.

All indications from our observations point to an increasing sea otter population which will continue to expand its range both north and south along the coast if left unhindered.

Distribution

The distribution of sea otters within their range is apparently limited by the type and amount of habitat available, carrying capacity of the habitat (i.e., the ability of a given area to support a given number of animals), number of sea otters present and the behavioral characteristics of the population.

Although sea otters live year-round in certain shallow areas in the Bering Sea without kelp beds (Kenyon, 1969), sea otters throughout their range are most often associated with nearshore rocky reefs which support kelp beds and the associated biological communities which provide the large food supply required by sea otters.

In central California, where sea otters have made their comeback, excellent areas of sea otter habitat with large beds of giant kelp, *Macrocystis pyrifera*, and/or bull kelp, *Nereocystis luetkeana*, with extensive surface canopies, occur almost continuously from Seaside to Cayucos. Monterey Bay with 48 km (30 miles) of sandy beaches provides a long break in this habitat from Seaside to Soquel Point near Santa Cruz, where suitable habitat occurs intermittently on up the coast. To the south, Estero Bay presents a shorter break in the rocky reef habitat with about 23 km (14 miles) of sandy beaches from Cayucos to Point Buchon, where another stretch of rocky reef - kelp bed habitat continues on to about Shell Beach. Suitable sea otter habitat occurs intermittently along much of the southern California coastline and around the channel islands of southern California.

Population Densities. Kenyon (1969) considered sea otter habitat at Amchitka to extend out to the 55 m (30 fathom) depth contour. Subsequently, other observers have used the 55 m (30 fathom) contour to determine sea otter densities at Amchitka and other islands in the north Pacific (Estes and Smith, 1973). On this basis, Estes and Smith calculated a density of 63 otters per square mile at Amchitka where they have recently estimated the population at nearly 7,000 animals.

Odemar and Wilson (1969b) considered sea otter habitat in California to extend out to the 18 m (10 fathom) depth contour and calculated densities on that basis. We feel that this is too conservative since it is not unusual to see animals in water beyond the 18 m (10 fathom) line. However, in California, sea otters rarely are seen in waters much deeper than 30 m (100 ft). Therefore, we consider that the 37 m (20 fathom) depth curve currently is more representative of the seaward limits of the sea otter habitat in California. As the population continues to grow, otters may have to forage deeper and we may have to consider a wider nearshore band to evaluate densities.

Sea Otter Game Refuge boundaries (Figure 1) provide convenient dividing lines for analyzing relative densities of sea otters in the California population in recent years. Using the 37 m (20 fathom) depth contour as a basis, there are approximately 303 $km^2$ (117 $miles^2$) of habitat between Seaside and

Point Estero and about 26 additional km$^2$ (10 miles$^2$) from Point Estero to Cayucos, which sea otters occupied in 1972. The area between Refuge boundaries amounts to about 238 km$^2$ (92 miles$^2$) of habitat.

Population estimates for 1968-1972 indicate that average annual densities for the entire population during this period ranged from 3.8 to 5.3 animals per km$^2$ (9.8 to 13.6 per mile$^2$), with an overall average of about 4.6 per km$^2$ (12 per mile$^2$) for the entire period (Table 2). However, the population density between Refuge boundaries from 1968 to 1972, which characteristically has been less than the overall density, ranged from only 3.2 to 4.9 sea otters per km$^2$ (8.4 to 12.8 per mile$^2$) with an overall average of about 3.9 per km$^2$ (10 per mile$^2$). This has resulted in an uneven distribution of sea otters throughout the total range with greater concentrations at the extremes of the range, where range expansion has been occurring. When the range was essentially between Seaside and Point Estero during 1968 through 1971, at times nearly half of the total number of sea otters counted on aerial censuses was concentrated north and south of Refuge boundaries (Table 3) in only 21% of the habitat. Thus, most of the population increase apparently has been supporting range expansion, resulting in significantly higher densities at the extremes of the range.

As sea otters moved into and became established in the Cambria - Point Estero area just south of the Refuge, the average annual density of sea otters in this area increased from 3.6 to 7.5 per km$^2$ (9.2 to 19.3 per mile$^2$) from 1968 to 1971 (Table 2). Then in 1972, the range was extended to Cayucos, where densities of about 8.1 per km$^2$ (21 per mile$^2$) were observed between Point Estero and Cayucos while a reduced density of otters remained in the Cambria - Point Estero area. A survey from shore in late 1972 still indicated densities of over 8.1 per km$^2$ (21 per mile$^2$) in the Cayucos Point area. This density was apparently sufficient to result in further range expansion across Estero Bay to Point Buchon in 1973.

At the northern end of the range, sea otters had extended their range to Seaside by 1968. However, the long sandy area within Monterey Bay has apparently delayed range expansion to the north. Densities between the north Refuge boundary and Seaside have been consistently higher than elsewhere. Average annual densities in this area (Table 2) have ranged from approximately 7.7 sea otters per km$^2$ (20 per mile$^2$) to nearly 12.0 sea otters per km$^2$ (31 per mile$^2$). The population is now apparently expanding across the bay where a very low density presently occurs.

Odemar and Wilson (1969b), on the basis of three census flights in 1969, concluded that the area just south of Point Sur (a small area within the major central portion of the range) was a relatively low density area. Subsequent censuses appear to support this conclusion. Our calculations indicate that average annual densities for the short stretch of coast between Point Sur and Partington Point, a distance of about 23 km (14 miles), from 1968 to 1972 ranged from only 1.0 to 2.7 sea otters per km$^2$ (2.6 to 6.9 per mile$^2$) with an overall average of about 1.9 per km$^2$ (5 per mile$^2$) during the entire period.

TABLE 2. Estimated Average Annual Densities of Sea Otters in California from 1968 - 1972.*

| | ENTIRE RANGE | | | BETWEEN SEA OTTER GAME REFUGE BOUNDARIES | | | NORTH OF REFUGE | | | SOUTH OF REFUGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Miles$^2$ of Habitat† | Area | Density (Otters/ Mile$^2$) | Miles$^2$ of Habitat | Area | Density (Otters/ Mile$^2$) | Miles$^2$ of Habitat | Area | Density (Otters/ Mile$^2$) | Miles$^2$ of Habitat | Area | Density (Otters/ Mile$^2$) |
| 1968 | 117 | Seaside - Pt. Estero | 9.8 | 92 | Carmel River - Cambria | 8.4 | 13 | Carmel River - Seaside | 19.8 | 11 | Cambria - Pt. Estero | 9.2 |
| 1969 | 117 | Seaside - Pt. Estero | 11.2 | 92 | Carmel River - Cambria | 9.5 | 13 | Carmel River - Seaside | 22.3 | 11 | Cambria - Pt. Estero | 11.3 |
| 1970 | 117 | Seaside - Pt. Estero | 11.8 | 92 | Carmel River - Cambria | 10.0 | 13 | Carmel River - Seaside | 20.8 | 11 | Cambria - Pt. Estero | 14.6 |
| 1971 | 117 | Seaside - Pt. Estero | 13.1 | 92 | Carmel River - Cambria | 9.7 | 13 | Carmel River - Seaside | 30.8 | 11 | Cambria - Pt. Estero | 19.3 |
| 1972 | 122‡ | Seaside - Cayucos | 13.6 | 92 | Carmel River - Cambria | 12.8 | 13 | Carmel River - Seaside | 21.8 | 16§ | Cambria - Cayucos | 11.6 |
| | | | | | | | | | | 11 | Cambria - Pt. Estero | 4.3 |
| | | | | | | | | | | 10 | Pt. Estero - Cayucos | 21.1 |

Breakdown of April 1972 count South of Cambria {

* See Appendix II, Sea Otter Density Calculation Data.

† Miles$^2$ of habitat for each area was calculated between the shoreline and 37 m (20 fathom) depth contour. 1 mile$^2$ = 2.590 km$^2$.

‡ Range during January and April counts (the only 1972 flights) was Seaside to Point Estero in January (116.9 miles$^2$) and Seaside to Cayucos in April (126.9 miles$^2$). These were averaged to get average habitat for 1972.

§ Within this area, there were 11.3 miles$^2$ of habitat occupied on the January 1972 flight and 21.3 miles$^2$ occupied on the April flight. These were averaged to get average habitat for 1972.

TABLE 3. Percentages of Aerial Sea Otter Counts Observed North and South of Sea Otter Game Refuge Boundaries from 1968 to 1972.

| Date | Aerial Count | % Observed North and South of Refuge Boundaries | % Observed North of Refuge | % Observed South of Refuge |
|---|---|---|---|---|
| Nov 1968 | 664 | 34.0 | 24.5 | 9.5 |
| Dec 1968 | 377 | 31.3 | 22.3 | 9.0 |
| Jan 1969 | 983 | 29.4 | 17.5 | 11.9 |
| Feb 1969 | 770 | 39.4 | 26.4 | 13.0 |
| Mar 1969 | 931 | 38.9 | 25.0 | 13.9 |
| Jun 1969 | 1014 | 26.9 | 23.0 | 3.9 |
| Aug 1969 | 529 | 29.5 | 18.3 | 11.2 |
| Oct 1969 | 483 | 35.2 | 26.3 | 8.9 |
| Dec 1969 | 649 | 29.6 | 23.3 | 6.3 |
| May 1970 | 1040 | 36.6 | 20.7 | 15.9 |
| Sep 1970 | 612 | 29.9 | 22.5 | 7.4 |
| Feb 1971 | 718 | 32.0 | 23.6 | 8.4 |
| Apr 1971 | 902 | 48.5 | 30.5 | 18.0 |
| Jul 1971 | 959 | 45.3 | 25.8 | 19.5 |
| Oct 1971 | 715 | 40.8 | 28.8 | 12.0 |
| Jan 1972 | 1060 | 20.4 | 13.3 | 7.1 |
| Apr 1972 | 770 | 43.0 | 31.2 | 11.8 |

Odemar and Wilson hypothesized that low densities in this area represented a division of the population into two major subgroups and discussed distribution on that basis. It is our opinion that there is not enough evidence to confirm nor deny this hypothesis. To do so will require more complete population dynamics information on animals throughout the central portion of the range, particularly on movements of otters. It is possible that this area has a relatively low carrying capacity. In addition, it is an area where sea otters apparently survived the fur trade and have persisted in the general area before and since with continual utilization of the food resources. The densities, therefore, may represent an optimal carrying capacity for this short stretch of habitat. Nevertheless, questions such as these do point out the need for a more thorough understanding of population dynamics, especially throughout the large central portion of the range.

Peterson and Odemar (1969) felt that the population within the major central portion of the range was reaching a maximal size in 1969. Information on the sea otter populations in the north Pacific indicates that considerable over-crowding will result in large natural die-offs, which reduce the population. The present densities in the center of the range in California probably do not represent over-crowding, and there is no evidence that large die-offs have occurred there. Our data indicate that the number within the central portion of the range is increasing, although more slowly than the total population (Figure 6), probably because the excess is resulting in range expansion. However, with continued population growth and range expansion a faster rate of increase is to be expected within the center of the range because of increasing distances to the peripheries of the range. Eventually, this undoubtedly will result in over-crowding and resultant extensive die-offs, which are characteristic of over-crowded populations elsewhere (Kenyon, 1969).

During the recent winter and early spring months of 1972-73, more than three times the number of carcasses was recovered than during any previous comparable period (see section on Examination of Sea Otter Remains). This was apparently a natural mortality due to a severe winter and some crowding at the extremes of the range, where most of the carcasses are usually found. The inaccessibility of much of the central range results in very few carcass recoveries and makes it difficult to determine mortality there. This recent die-off is probably only the beginning of what will become an occurrence of increasing proportions as the California population continues to increase.

Sexual Segregation. Sexual segregation in sea otter populations has been described by Lensink (1962), Kenyon (1969) and Schneider (1972). This knowledge was used by Estes and Smith (1973) to evaluate effects of the Cannakin atomic blast at Amchitka. Kenyon reports that this behavior is more pronounced among adults and subadults than among younger independent animals. Male areas reportedly tend to be less numerous, smaller and more densely populated than female areas. Kenyon reported that sexually active males move into female areas in search of estrous females. We have observed this behavior in California also.

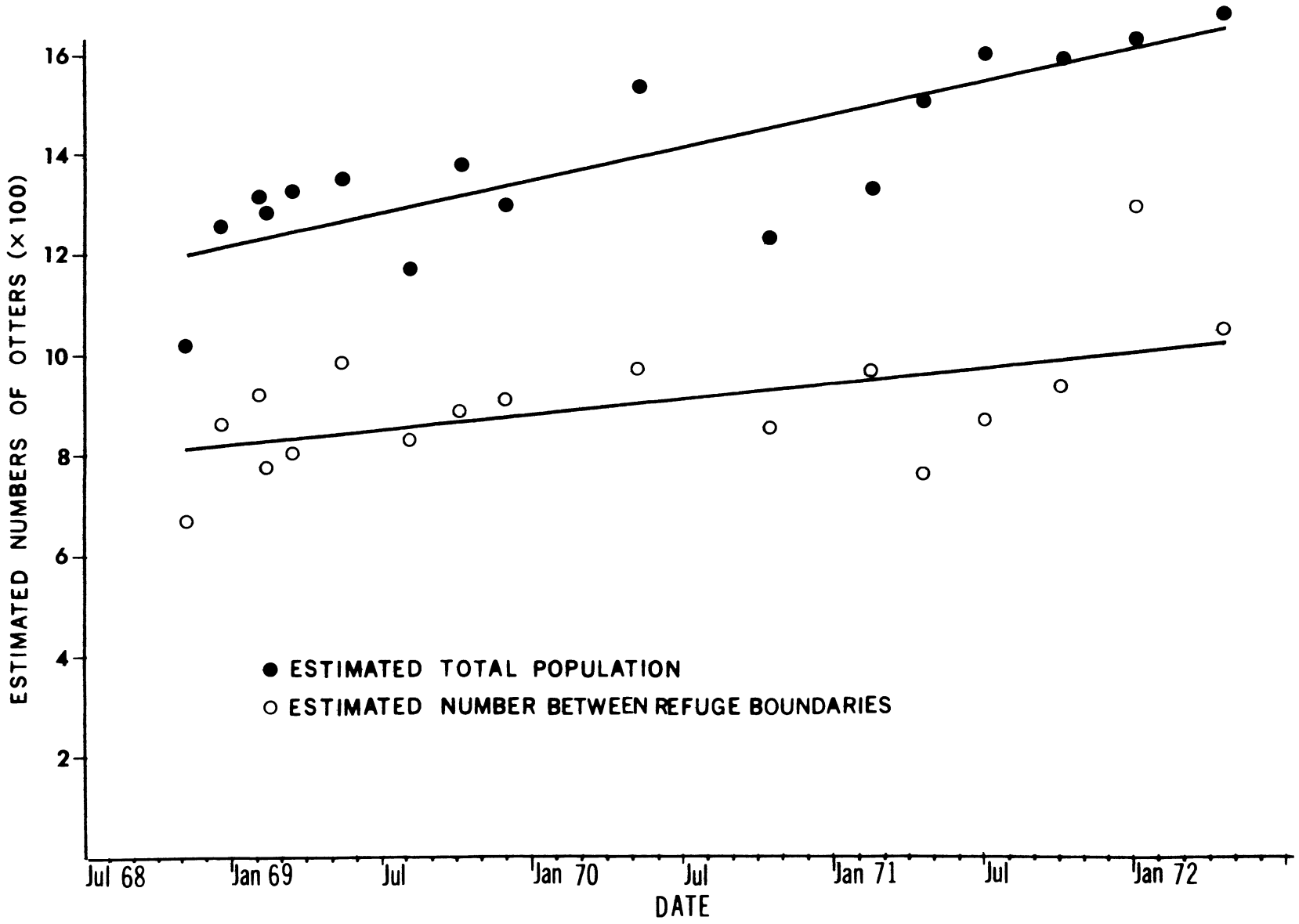


FIGURE 6. Regressions of estimated total sea otter population in California and estimated numbers of sea otters between north and south Sea Otter Game Refuge boundaries from October 1968 through April 1972. Y = a + bx ●: a = 1160; b = 10.7 o: a = 789; b = 5.7

Our limited trapping operations in selected locations at the extremes of the range indicate that sexual segregation is also characteristic of the California population. At the extreme southern end of the range, 26 sea otters were captured with gill nets in 1969 in the vicinity of Cambria Air Force Radar Station. All but one of these, a subadult female, were males.

In 1972, we trapped with the diver-held device at the southern end of the range. Six sea otters captured at Cayucos Point, then the extreme southern end of the range, and six sea otters captured just north of Point Estero were all males. Three sea otters captured in the vicinity of Cambria were all females.

Since all of the available evidence indicated that the southern expanding fringe was occupied by males, it seemed likely that the extension of the expanding fringe to Point Buchon in 1973 consisted of males. In early 1973, at least two of the male sea otters we tagged in the Point Estero - Cayucos area were observed off Point Buchon, further supporting the assumption that this newly colonized area was occupied primarily by males.

At the northern end of the range, seven sea otters were captured off Monterey's Cannery Row in 1970, 1971 and 1972. Only two of these were females, one of which was a subadult. Both females were captured in 1970. Field observations have confirmed that the Cannery Row area is a male area.

Ten female sea otters were captured in late 1972 off Del Monte Beach in the vicinity of the Monterey - Seaside border, then the extreme northern end of the established range, delineating this as a female area. Since trapping at the southern end of the range in 1969 and 1972 had demonstrated that the southern expanding fringe was a male area, we were surprised to learn that the extreme northern fringe of the range in 1972 was a female area. This may have been a female area since 1968, which could explain the different expansion pattern described in the section on range expansion which occurred between Point Pinos and Seaside from 1968 to 1972. Apparently, in this case, a female area had been established beyond the expanding male fringe. However, both male and female carcasses have been recovered in the area and adult males have been seen in the kelp bed.

We do not know whether the animals being observed off Santa Cruz are males or females, although of nine carcasses recovered in the vicinity of Moss Landing from 1969 to 1973, five have been adult males; only one was an adult female. The remainder includes a subadult female and two younger animals of undetermined sex.

Females with small pups help to identify female areas, although the absence of pups does not necessarily define male areas. We observed no pups off Del Monte Beach prior to or during our trapping operations there. Also, large males have been observed to tolerate recently weaned immature males which may continue to exhibit mother-pup behavior by floating next to a mature male in male rafting areas.

Recently a female with a pup has been observed off Del Monte Beach. Females with pups are now commonly observed off the Point Pinos - Lovers Point area. The Carmel - Point Lobos area is a well known pupping area. Females with pups are observed throughout the central portion of the range and south to at least Cambria, where they have been commonly seen since 1971. Male areas, very likely, occur in the central portion of the range. However, the only certain way to establish male-female areas is by capturing and tagging a significant number of animals throughout the range. This needs to be done, particularly throughout the area along the Sea Otter Game Refuge, since we have the least information about this large area.

Age Groupings. Techniques of aging sea otters have not been refined to the same degree as for many other mammals. Sea otter skulls can be divided into general age categories based on the extent of calcification which results in suture fusion and ridge formation and on tooth development and wear.[3/]

Schneider (1972) experimented with sectioning and staining sea otter teeth for age determination. He reportedly obtained a correlation of estimated ages from this method with body size measurements, numbers of corpora albicantia, age of sexual maturity and age classes based on tooth eruption in animals obtained in Alaska Fish and Game harvesting operations. Schneider stated that "The irregularity of cementum layers, presence of confusing secondary lines, faintness of the early lines and variable birth dates make it impossible to precisely determine the age of most sea otters." He concluded that these estimated ages may be in error by 1 or 2 years. Further refinement of this method should increase its reliability.

Schneider classified sea otters captured or killed in harvesting operations in Alaska from 1967 through 1970 into pups, subadults and adults, using a variety of methods. He considered males under 11.3 kg (25 lb), females under 9.1 kg (20 lb), and both with a total curvilinear length of less than 100 cm (39 inches) as dependent pups. Females under 15.9 kg (36 lb) and shorter than 120 cm (47 inches) and males under 20.4 kg (45 lb) and shorter than 130 cm (51 inches) were considered subadults. Larger animals were considered adults.

While it was not possible to obtain lengths of live animals we captured, the respective weights obtained during these operations can be used to provide a general picture of age groups in our limited areas of tagging.

In all, 58 sea otters (42 males, 16 females) have been captured during project operations from 1969 through 1972. Weights were obtained on all but five and provide some information on age groupings in selected areas at the extremes of the range (Tables 4 and 5).

---

3/ A relative aging guide is being developed using these characteristics as a basis by G. Victor Morejohn at Moss Landing Marine Laboratories, Moss Landing, California.

TABLE 4. Number, Weight and Approximate Age of Male Sea Otters Captured in California from 1969 through 1972.

| | Cambria A.F. Radar Station * | Pt. Estero | Cayucos Pt. | Monterey | All Areas |
|---|---|---|---|---|---|
| Year | 1969 | 1972 | 1972 | 1970-1972 | 1969-1972 |
| Number of Otters | 21 | 6 | 6 | 5 | 38 |
| Weight Range | 16-34 kg (36-76 lb) | 28-39 kg (61-86 lb) | 10-30 kg (21-66 lb) | 16-32 kg (36-71 lb) | 10-39 kg (21-86 lb) |
| Average Weight | 26.1 kg (57.6 lb) | 33.2 kg (73.2 lb) | 18.6 kg (41.0 lb) | 24.2 kg (53.4 lb) | 25.6 kg (56.4 lb) |
| No. of Adults† | 19 | 6 | 2 | 3 | 30 |
| No. of Subadults† | 2 | 0 | 4 | 2 | 8 |

* Cambria Air Force Radar Station is located about 6 km (4 miles) south of Cambria.

† Considered adult if 20.9 kg (46 lb ) and over, subadult if 20.4 kg (45 lb ) and under.

TABLE 5. Number, Weight and Approximate Age of Female Sea Otters Captured in California from 1969 through 1972.

| | Cambria A.F. Radar Station* | Monterey | Cambria | Del Monte Beach† | All Areas |
|---|---|---|---|---|---|
| Year | 1969 | 1970 | 1972 | 1972 | 1969-1972 |
| Number of Otters | 1 | 2 | 3 | 10 | 16 |
| Weight Range | -- | 15-18 kg (34-40 lb) | 12-24 kg (27-54 lb) | 11-21 kg (25-46 lb) | 11-24 kg (25-54 lb) |
| Average Weight | -- | 16.8 kg (37.0 lb) | 16.9 kg (37.3 lb) | 16.2 kg (35.7 lb) | 16.4 kg (36.2 lb) |
| Number of Adults‡ | 0 | 1 | 1 | 5 | 7 |
| Number of Subadults‡ | 1 | 1 | 2 | 5 | 9 |

* Cambria Air Force Radar Station is located about 6 km (4 miles) south of Cambria.

† Del Monte Beach is located near the Monterey-Seaside Border.

‡ Considered adult if 16.3 kg (36 lb) and over, subadult if 15.9 kg (35 lb) and under.

In 1969, the area off Cambria Air Force Radar Station was occupied largely by adult males. Only one female, a subadult, has been captured in the area south of Cambria. In 1972, this general area was apparently still occupied by adult males since no subadult males and no females were captured in our operations just north of Point Estero.

At the same time in 1972, off Cayucos Point, where otters had only recently extended their range, a higher percentage of subadult males was captured.

In the Monterey area, a small sample obtained from 1970 to 1972 produced nearly equal numbers of adult and subadult males. In this same area off Cannery Row, which we consider a male area, two females, one adult and one subadult, were captured in 1970.

In 1972, in a nearby area off Del Monte Beach, near Seaside, then the extreme northern end of the established range, 10 captured females were evenly divided between adults and subadults. None of the adults were particularly large.

Toward the southern end of the range in 1972, in the vicinity of Cambria, one adult and two subadult females were captured in an area where females with pups are being more commonly seen.

The data on age groupings indicate that range expansion is accomplished largely by subadults and younger adults of both sexes.

The female area at the northern extreme of the range in 1972 off Del Monte Beach was composed mostly of subadults and young adults. Of the five males taken off Cannery Row, two were subadults and one 24.0 kg (53 lb) animal was a young adult.

The small sample in the southernmost female area in 1972 in the vicinity of Cambria yielded two subadults to the single adult captured.

Off Cambria Radar Station in 1969, after otters had been in the general area since 1967, 7 of the 19 adults were in the 20.8 - 22.7 kg (46 - 50 lb) young adult range; in addition, 2 subadults were taken. In this same area in 1972, after the range had been expanded to Cayucos, no males under 29.9 kg (66 lb) were captured.

At the same time in 1972, off Cayucos Point, then the extreme southern end of the range, four of six captured males were subadults.

Since we have done no sea otter capturing throughout the major central portion of the range, age composition data are lacking for most of the population. More information on age groupings throughout the range is needed to fully understand the population structure and its relationship to range expansion.

Movements. Kenyon (1969) reported on results of tagging 224 sea otters at Amchitka from 1956 to 1963. Only 28 tag recoveries were subsequently recorded and the information obtained was considered meager. However, Kenyon concluded that the home range of a female sea otter may include 8.1 to 16.1 km (5 to 10 miles) of coast and that males may have a larger home range than females. Although six tags from young males were recovered, only one of 30 adult males tagged was recovered. This was an animal which became used to being hand fed at a dock and its behavior may not have been representative of a normal adult male.

Kenyon also concluded that animals tagged on one side of the island did not move around to the other side.

In our operations, 46 sea otters have been tagged and released, including 22 males and 14 females. Only three tags have been recovered. Several others have been observed from shore, but the tag numbers usually have not been discernible.

Two tag recoveries were from carcasses of animals which were translocated in 1969 from Cambria to Big Creek and were known to have moved nearly 72.4 km (45 miles) back to the vicinity of tagging. These two animals were at liberty nearly 11 months.

Tag sightings indicate that at least 5 of 17 male sea otters made the journey back to the area of tagging (see section on Translocation within the Range), in some cases within 2 months after translocation (Odemar and Wilson, 1969c).

The only other tag recovery was from a moribund adult female, tagged in December 1972, 3 months before recovery. This animal, which died shortly after recovery, had been tagged just offshore from the recovery site at Del Monte Beach near the Monterey-Seaside border.

A subadult male and a young adult female tagged off Monterey in 1970 were observed in the area only for a brief time and have not been reported since.

An adult male tagged off Monterey on April 29, 1971, during development of the diver-held capture device, was subsequently observed on numerous occasions by a number of different observers during a period of nearly 15 months. This animal was observed by several persons in the rafting area off Monterey and in the Monterey Marina through June 1971. Then in August, it was reported at Point Lobos, 27.4 km (17 miles) south along the coast, in a female-pupping area. In October, this otter was reported at Point Lobos and at Monterey within a period of 5 days. In November it was reported several times at Point Lobos and twice at Monterey, on one occasion 4 days before being seen at Point Lobos. It was observed several times at Point Lobos in December, apparently mated with a female. During January and February it was reported a few times in the Monterey area and once was reported about half way between Point Lobos and Monterey. The

last record we have of this animal was an observation by one of the authors at Point Lobos July 9, 1972. The tag at this time was quite loose in the webbing of the foot and very likely has subsequently been lost.

At least two and possibly more (since tag numbers were not discernible) of the male otters tagged at the southern end of the range in December 1972 were subsequently observed at least 23 km (14 miles) south when range expansion to Point Buchon was accomplished in early 1973.

Observations at Amchitka may not be directly comparable to ours, since the Amchitka population had occupied all of the available habitat for several years when tagging was accomplished, while the California population is still expanding its range. Nevertheless, our data do support Kenyon's conclusion that the male sea otter's home range is probably larger than the female's. This is probably due in part to movements of males into female areas for mating.

Our data also suggest that some of the animals in concentrations at the extremes of the range move into adjacent vacant habitat as food resources become depleted.

Whether animals in the concentrations at the extremes of the range come from any significant distance within the center of the range is not known for certain. Data in the section on Population Densities suggest that they do. Tagging a significant number of animals throughout the range could provide conclusive evidence.

## Examination of Sea Otter Remains

Prior to 1968, records were kept primarily on sea otter carcasses or portions thereof which were loaned to educational and scientific institutions by Departmental permit to comply with the fully protected status of sea otters. Decomposed carcasses were usually buried. Since its inception in July 1968, the Sea Otter Project developed and continued a program of sea otter carcass recovery, processing and distribution of remains to obtain information on causes and levels of mortality. Efforts were made to recover all carcasses reported. Carcass materials were provided to a number of researchers at various institutions for scientific studies on taxonomy, anatomy, physiology, environmental contaminants, food habits and parasitism in sea otters. A numbering system was devised to simplify bookkeeping for carcass handling and disposition.

### Numbers and Locations of Carcass Recoveries

From July 1968 through June 1973, 222 sea otter carcasses were recorded; nearly all were recovered. Except for a small peak in the numbers of carcasses in 1970, when 51 carcasses were recorded, the numbers did not fluctuate significantly from 1969 through 1972. However, in early 1973 a significant increase in the number of carcasses occurred (Figure 7). From

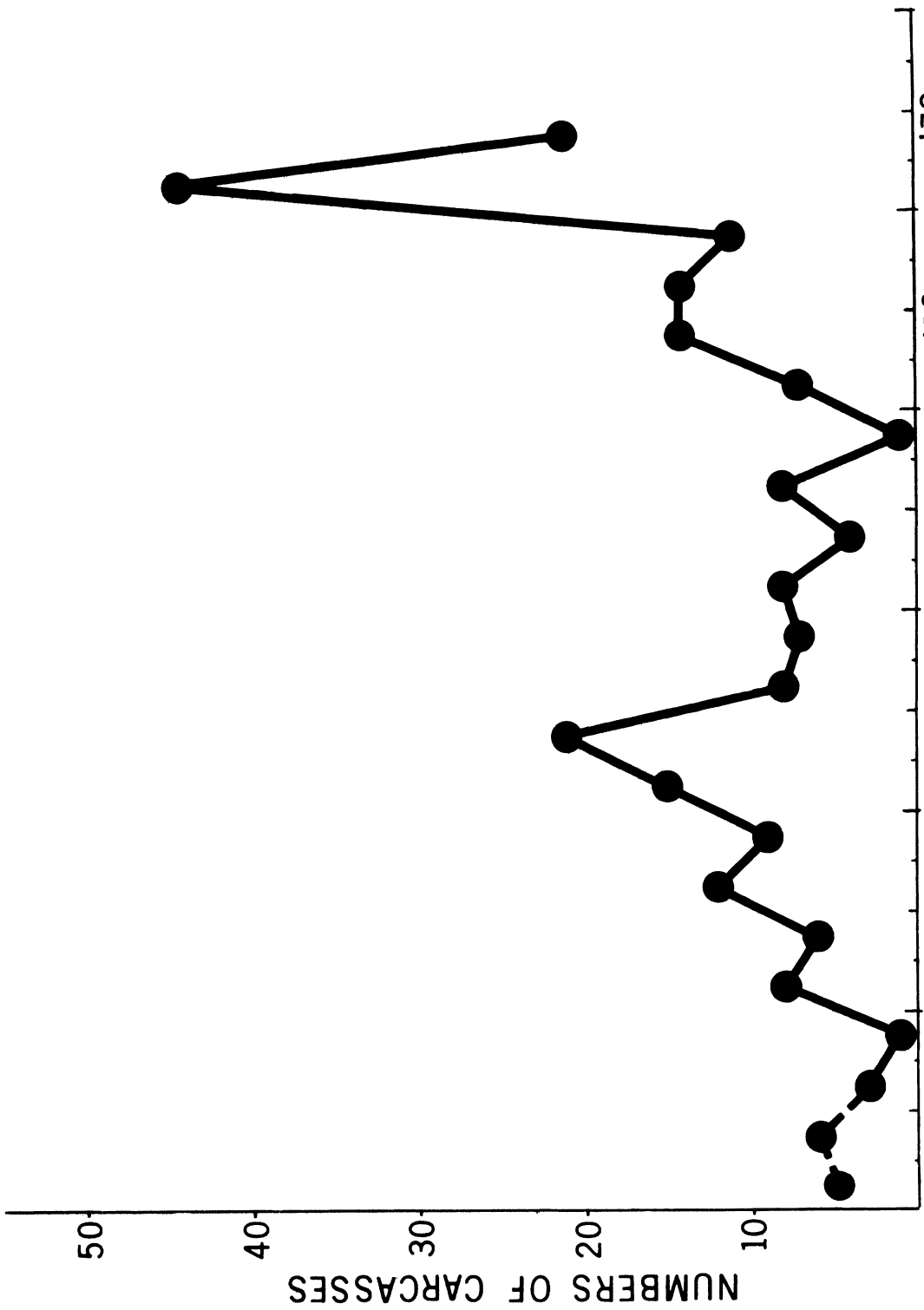


FIGURE 7. Numbers of sea otter carcasses recorded in California during each annual quarter from 1968 through June 1973.

January through June 1973, 65 carcasses were recovered. The probable reasons for the peaks are discussed in the section on Cause of Death.

Carcass recoveries have been concentrated at the northern and southern ends of the sea otter's range (Figure 8). These two areas, which comprise less than a third of the current range, accounted for 84% of all carcasses recorded from July 1968 through June 1973; 124 (56%) came from between Seaside and Yankee Point and 62 (28%) came from between San Simeon Point and the south end of Estero Bay. Only 15 (about 7%) of the carcasses have come from the 148 km (92 mile) stretch of coast between Point Sur and San Simeon Point. No carcasses have been recovered from a major portion of this area during our collections (Figure 8). The remainder came from north of Seaside and south of Estero Bay. The exact origin of three carcasses is unknown.

Several factors are probably responsible for the concentrations of carcass recoveries. Included are: Proximity of human population centers; ease of coastal access and a general public awareness of, and interest in sea otters, all of which result in a high incidence of carcass reporting; concentrations of human activities such as boating, skindiving and fishing, which account for some sea otter fatalities; and concentrations of the expanding sea otter population in these areas with resultant depletion of food supplies (see section on Population Densities).

The low incidence of carcass recoveries throughout the major central portion of the range is probably due, in part, to the ruggedness and inaccessibility of much of this area. It may also be due to the lower density of animals which occurs there. Kenyon (1969) reports that the rate of sea otter mortality was considerably less for low density populations around certain islands in the north Pacific.

A few carcasses have come from areas well beyond range boundaries in recent years. Two have come from Point Reyes, north of San Francisco, since 1970 and one was found at San Miguel Island in 1971 (see section on Range Expansion).

The location of a carcass recovery does not always provide a precise location of where the animal died. Sea otters rarely come ashore in California, although some may be more apt to when in distress. Nevertheless, most of the deaths probably occur in the water and, since sea otter carcasses float, they usually wash ashore.

Several carcasses in recent years have been recovered at the south end of Estero Bay beyond what was the southern end of the range prior to 1973. These carcasses presumably drifted across the bay and washed ashore on beaches or the sand spit in the vicinity of Morro Bay.

Some of the carcasses found in the area from Seaside to Moss Landing near the north end of the range probably drifted in from the Monterey - Pacific Grove area. Because of drifting carcasses, precise information

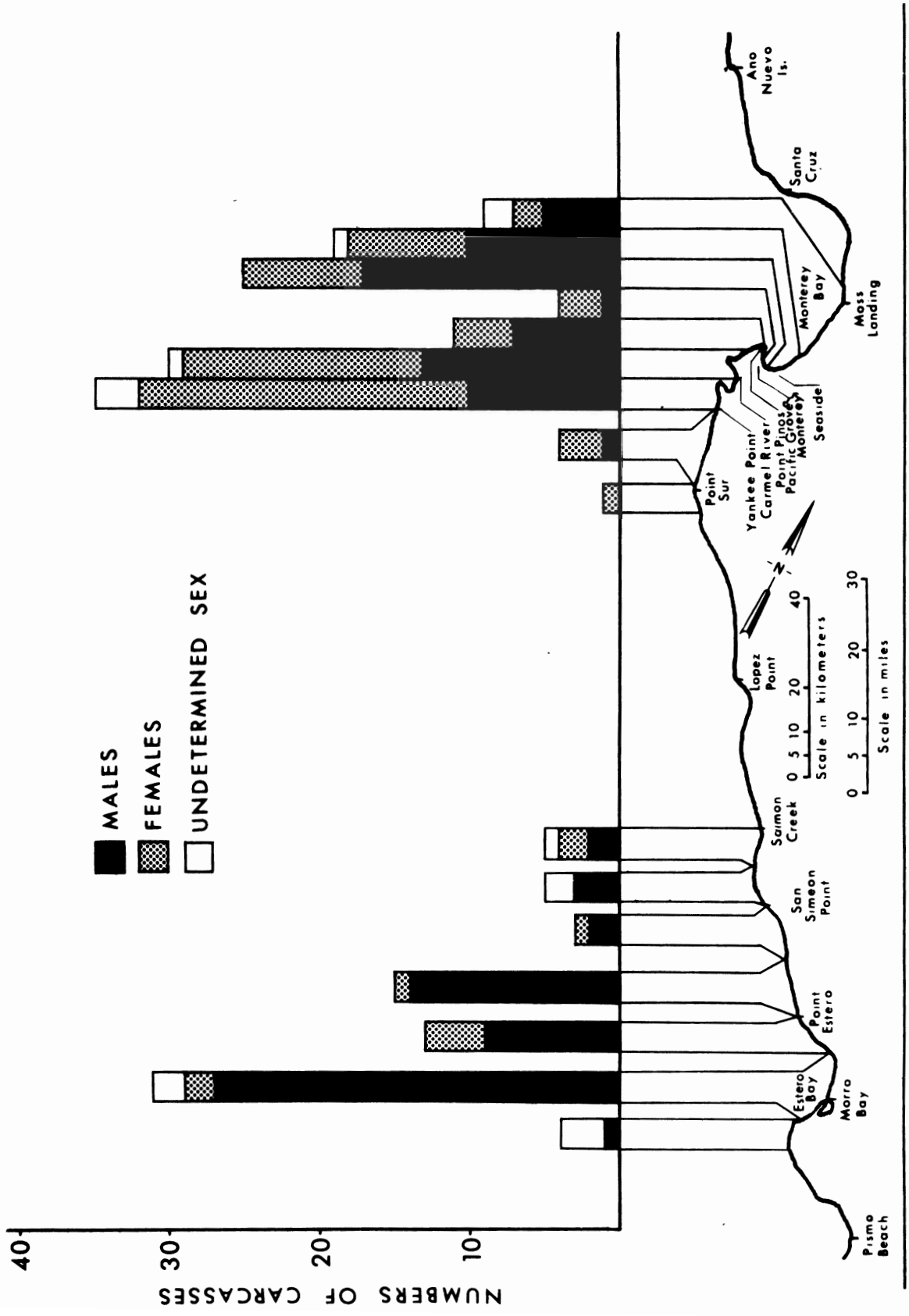


FIGURE 8. Location and sex of sea otter carcasses recorded in California from Santa Cruz to Pismo Beach from July 1968 through June 1973.

on male-female areas cannot be determined from carcass recoveries. A majority of carcasses probably are recovered within a general vicinity of where the animal died so that some trends are indicated.

Sex and Age Composition of Carcasses

Of all carcasses recorded from July 1968 through June 1973, 125 were males, 78 were females and 19 were of undetermined sex. At least eight of those of undetermined sex remain to be necropsied before sex will be determined.

A majority of the carcasses from the southern end of the range were males (Figure 8). This is not unexpected since tagging studies have indicated that the southern expanding fringe has been occupied mainly by males.

At the northern end of the range, a majority of the carcasses recovered in the area from Carmel to Point Sur have been females, while a majority of those from the Monterey area have been males. The data suggest the possibility of a male area just south of Point Pinos, since a majority of the few carcasses recovered in this area were adult males. The number of female carcasses in the Monterey to Seaside area suggests the probability of a female area in the vicinity since most of these female carcasses were adults and subadults. The evidence for a female area off Del Monte Beach near the Monterey-Seaside border is discussed in the section on Sexual Segregation.

During 1969 and 1970, approximately 2/3 of all carcasses were adults, while most of the remainder were subadults. A few pups were recovered during this period (Table 6). In 1970, the carcasses were evenly divided between adults and subadults. During 1972 and 1973, nearly 2/3 of all carcasses were subadults and pups. In 1973, a significant peak in carcasses of all ages occurred during the first half of the year (Figure 7); larger numbers of subadults and pups were recovered during this period than during any previous entire year (Table 6).

Cause of Death

The condition of carcasses when found ranges from portions of skeletons or badly decomposed remains to very fresh remains. At times moribund otters are recovered which die soon thereafter. Carcasses in good to fresh condition provide the best indications of cause of death. Only fresh carcasses known to have died within a matter of a few hours before recovery are satisfactory for determination of tissue pathology.

Some indication of cause of death, such as evidence of external injuries, is at times apparent when a carcass is recovered. Additional information has been obtained from necropsies conducted on selected carcasses. A total of 88 necropsy reports was compiled from July 1968 through June 1973. Necropsies were conducted by project personnel and other qualified persons in mammology, medical and veterinary fields. Causes of death on 13 sea otters were analyzed by Mattison and Hubbard (1969). A number of carcasses from late 1972 and early 1973 remain to be necropsied.

TABLE 6. Sex and Approximate Ages of Sea Otter Carcasses Recovered in California from July 1968 through June 1973.*

| | Adult | | | Subadult | | | Pup | | | All | All |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | ? | Male | Female | ? | Male | Female | ? | Adults | Young† |
| 1968 Jun-Dec only | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 1969 | 15 | 5 | 0 | 2 | 4 | 0 | 3 | 0 | 0 | 20 | 14 |
| 1970 | 25 | 6 | 1 | 4 | 7 | 0 | 1 | 2 | 0 | 32 | 19 |
| 1971 | 9 | 0 | 1 | 4 | 6 | 0 | 0 | 0 | 0 | 10 | 10 |
| 1972‡ | 13 | 5 | 0 | 8 | 7 | 1 | 2 | 5 | 1 | 18 | 26 |
| 1973‡ Jan-Jun only | 16 | 9 | 1 | 6 | 13 | 2 | 7 | 5 | 6 | 26 | 39 |

* Animals for which no indication of sex or age was available are excluded from the table.

† Includes some young for which a sub-category was not determined and, thus, were not included in pup and subadult columns.

‡ Some ages are only tentative until all carcasses are examined. Some listed as adults are probably subadults and a few in pup and subadult categories may overlap.

No indication of cause of death was obtained on at least 62 carcasses. Most of these were badly decomposed or in some cases were only portions of a carcass. A few were good carcasses which were provided for freeze-dry taxidermy processing, oil cleaning experiments, or other scientific or educational uses which required an entire carcass.

Four sea otters drowned in nets during Departmental tagging and translocating studies. An additional otter was drowned in a net being fished in Elkhorn Slough near Moss Landing.

Four sea otters have died in captivity, three at the Biological Sonar Laboratory, Fremont, California, and one at Sea World, San Diego, California.

Trauma which appeared to have caused or contributed to cause of death was observed in at least 69 carcasses. Possible causes of traumatic injuries include being dashed on rocks, particularly in weakened animals, during prolonged storm conditions; boating accidents; nasal injuries to females during mating activities; fighting; and injuries intentionally inflicted by humans, including spearing, shooting or blows.

At least 22 carcasses showed evidence of being hit by a boat propeller. This is usually characterized by a series of parallel gashes which may be on the animal's side, dorsal, or ventral area, depending upon what the animal was doing when it was hit. A few more animals may have been hit by boats, but it was not always readily apparent from the wounds.

Shooting was determined as a cause of death in six carcasses from which bullets or shotgun pellets were recovered. At least nine additional carcasses had wounds which indicated possible shooting and a few more had penetrating wounds which could have resulted from shooting or spearing. Of the 15 carcasses which were definitely or most likely shot, 12 occurred from late 1969 through mid-1970. There is little indication that shooting has been much of a problem since 1970.

Analysis of boating and shooting deaths indicates that animals were more likely to be hit by a boat at the north end of the range, while they were more often shot at the south end of the range (Table 7).

TABLE 7. Area of Recovery of Sea Otter Carcasses Hit by Boats and Shot in California from July 1968 through July 1972.

| | North End of Range | South End of Range | Total |
|---|---|---|---|
| Number hit by boats | 16 | 6 | 22 |
| Number shot | 3 | 12 | 15 |

Of 86 carcasses recovered in 1969 and 1970, more than 20% were animals that died during capture, in captivity or were illegally shot. Most of these mortalities occurred in animals from the southern end of the range (3 capture drownings, 3 captive deaths and 10 shootings). Most of the shootings were most likely due to commercial abalone fishermen who, by 1971, were forced to abandon the once very productive red abalone beds north of Morro Bay because of foraging activities of an expanding sea otter population (see Food Habits Section and Appendix I). Three commercial fishermen were arrested by Departmental wardens and were convicted of shooting sea otters in 1970. It is rumored that 40 to 50 sea otters may have been shot during this period (Warden Captain W. Klein, CDFG, pers. commun.), which, with the foregoing information, helps to explain the peak in carcasses in 1970.

Another traumatic cause of death occurred in an immature female which was found in a moribund condition with a piece of monofilament fishing line wound tightly around and cutting into its chest, possibly preventing adequate respiration. This animal was treated by a veterinarian, but died of stress several hours after being found.

Although there is little evidence that fighting is a serious problem among sea otters, we observed nicks and cuts, both fresh and healed, on some of the large adult males we captured at Point Estero, which suggested the probability of fighting. We also observed on a captured male a large nose scar, which was similar to nose scars on females from mating encounters. While these wounds would not be likely to cause death, it is possible that they could become infected with resultant complications.

Further evidence that human activities do not account for all traumatic injuries is available from Amchitka where, of 83 carcasses examined in 1959, 21 had possible physical injury indicated (Kenyon, 1969). No indication of human causes was mentioned.

Other causes of death include infection or starvation with associated symptoms of hemorraghic enteritis and other stress symptoms; drowning, which may be secondary to trauma, infection or starvation; intestinal parasitic infestations; and occasionally performations of the gut from food debris or parasites with resultant peritonitis.

One adult female in excellent condition with considerable body fat apparently died attempting to give birth simultaneously to twin fetuses. Twinning is quite rare in sea otters and a female probably could not adequately care for two pups if they were born successfully.

A considerable weight loss prior to death is common in sea otters dying from starvation or other prolonged stress conditions. As much as a fourth to a third of the body weight may be lost fairly rapidly under such conditions. A 21 kg (46 lb) female we captured and tagged in December 1972 weighed only 14 kg (31 lb) when recovered in a moribund, emaciated condition 3 months later. For this reason, length-weight ratios of most beach dead animals are of little use for age determinations.

There is little evidence that predation by other animals causes any significant mortality in sea otters in California. Sharks have occasionally been implicated in sea otter deaths (Orr, 1959; Kenyon, 1969). One of the carcasses we examined had a series of cuts which might have been due to a shark bite.

There is less evidence that killer whales prey to any extent on sea otters. Several observations have been made of sea otters and killer whales in the same vicinity in Alaska (Kenyon, 1969) and in California with little indication of awareness of each other by either the otters or whales.

Bald eagles have been determined to prey on live sea otter pups at Amchitka (Estes and Smith, 1973), but we have no evidence that anything similar presently occurs in California.

The overall minimum of predation by other animals is probably a factor in the remarkable comeback of sea otters in most areas where remnant populations persisted after the fur trade of the 1700's and 1800's.

During the winter and early spring of 1972-1973, a significant increase in carcass recoveries occurred (Figure 7, Table 6). From January through June 1973, 65 carcasses were recovered, 55 of which occurred from January through April. This is more than 2-1/2 times the highest number in any previous comparable January to April period. There was little evidence of external injuries among the carcasses. Furthermore, the relatively severe winter conditions with extended periods of storms and rough seas undoubtedly resulted in much less boating, fishing and skindiving activities during this period.

Although many of the carcasses remain to be necropsied, it is evident that a significant majority of them are in the independent young (subadult) and pup age groups (Table 6). Several carcasses were apparently aged adults. In all probability some of those tentatively listed as adults will be in the subadult category when skulls are processed for aging.

Kenyon (1969) reports that a female may abandon a pup when it becomes difficult to obtain enough food for both of them, particularly during severe winter storm periods. Such behavior could account for the large number of pup carcasses recovered during late 1972 and early 1973 (Table 6).

Many carcasses of independent subadults (juveniles) at Amchitka during winter-spring die-offs were found to have malocclusions of the teeth which occurs when permanent teeth are erupting. This probably makes foraging more difficult during these periods. Eventual examination of skulls will determine whether this is a significant factor in the large number of subadult carcasses we recovered during early 1973. Nevertheless, significant numbers of the carcasses were in this age group during late 1972 and early 1973. Animals in this age group are also probably less skilled at foraging, which is a problem particularly during severe winters.

Several of the carcasses were aged adults as determined by size and badly worn and broken teeth. This condition makes foraging more difficult particularly on small hard-shelled organisms, which animals may have to eat more of, where food supplies are depleted.

Of the 65 carcasses recovered from January through June 1973, 37 were in good to fresh condition. Of these, 12 (more than 30% of the 37) which were mostly fresh carcasses, have been necropsied. The most common observations are emaciation, hemorrhagic enteritis and pneumonia. In some cases, heavy acanthocephalan parasite loads were present in the gut.

The age groups affected and the symptoms observed indicate a natural mortality due to crowding and depleted food supplies, primarily at the extremes of the range, combined with relatively severe winter conditions. These observations parallel those reported at Amchitka where high late winter - early spring die-offs are common (Kenyon, 1969). The high incidence of human caused deaths in recent years may have been a factor in delaying or reducing the severity of winter die-offs in California. As the population continues to grow and expand in California, increasing winter-spring die-offs similar to that which occurred in 1972-1973 can be expected.

More detailed analyses of necropsies will be published separately by various researchers who have been involved in the necropsy program.

Other Scientific Studies of Remains

Taxonomy. Decomposed carcasses, skulls and other skeletal remains were provided to Aryan Roest of California Polytechnic State University at San Luis Obispo for taxonomic studies of sea otters. On the basis of a large quantity of materials which he examined from sea otter populations from the Aleutian Islands, mainland Alaska, and California, Roest (In press) recognizes only two subspecies of sea otters, *Enhydra lutris lutris* and *E. l. gracilis*. Roest does not consider *E. l. nereis* to be a valid subspecies.

*E. l. lutris* ranges through the Commander and Aleutian Islands to Prince William Sound, Alaska, and includes a disjunct population in California. In recent years, otters from Amchitka have been translocated to southeastern Alaska, British Columbia, Washington, and Oregon. According to Roest, the California population represents the southern extreme of a cline which originally involved a continuous distribution of sea otters along the entire Pacific coast of North America.

*E. l. gracilis* is found around the Kurile Islands and the southern tip of the Kamchatka peninsula of Siberia. *E. l. gracilis* as described by Barabash-Nikoforov (1947) on the basis of very few specimens appears to be a valid subspecies although Roest did not examine materials from these populations.

Anatomy and Physiology. G. Victor Morejohn at Moss Landing Marine Laboratories is studying sea otter skulls and baculae for determination of relative age classes in sea otters. He is developing a relative aging guide based on extent of ossification and teeth condition in sea otter skulls.

Carcass materials provided to Hopkins Marine Station of Stanford University, Pacific Grove, have been used for a complete anatomical description of the sea otter's forelimbs (L. D. Howard, in press). Howard is working on a similar description of the sea otter's hindlimbs.

Three carcasses and an additional pair of kidneys have been provided to Vermont State University where anatomical and physiological studies of the sea otter's kidneys are in progress by Roy Horst of VSU and Fred Tarasoff of Nova Scotia Teachers College.

Environmental Contaminants. Sea otter tissue samples have been provided to the Department's Pesticide Laboratory, Hopkins Marine Station, and Moss Landing Marine Laboratories to test for chlorinated hydrocarbon pesticides (DDT and its derivatives DDD and DDE), polychlorinated biphenyls (PCB's) and trace and major elements.

Although levels of DDT and its derivatives in sea otter tissues show wide variances, they are generally lower than those found in sea lions and brown pelicans (Table 8). However, except for fatty tissues, the harbor seals tested had lower levels than those found in sea otters. Since chlorinated hydrocarbons have an affinity for fatty tissues, animals with thick blubberlike layers such as sea lions and harbor seals generally show much higher levels in these fatty tissues than sea otters, which have no blubber and relatively little body fat. Lower levels in sea otter tissues relative to some other marine mammals and birds is attributed to sea otters' feeding at a lower trophic level.

Levels of DDE, the main residue of the pesticides tested, have been conducted on an additional 31 samples of sea otter liver tissues at Hopkins Marine Station. These DDE levels fall within the range of total DDT in sea otter tissues in Table 8 (James Rote, pers. commun.), although the mean (3.2 ppm) is slightly higher for these additional samples which came mostly from 1971 to 1973 carcasses.

Sea otter tissues also show quantifiable levels of PCB's (Jack Linn; James Rote, pers. commun.). The liver tissues tested for DDE are also being tested for PCB levels by Rote, but the results were not available at the time of this writing. His preliminary analysis indicates that all of the samples show a pattern which matches industrial PCB's.

Tests for a wide range of trace and major elements in sea otter kidney, liver and muscle tissues have been conducted by John Martin at Moss Landing Marine Laboratories (Table 9). These levels will provide the basis for analysis and comparison with additional sea otter samples and other animals. Martin is currently performing statistical analyses on the relationship of these elements to age, weight, sex, year and season collected, cause of death, food habits, etc., in an attempt to understand the significance of the levels observed. Levels in sea otter tissues are also being compared with sea lion tissues. A preliminary observation is that sea otters

TABLE 8. Levels (ppm) of DDT and Its Derivatives DDD and DDE in Various Tissues of Sea Otter, California Sea Lion, Harbor Seal, Brown Pelican and Murre in California.

| | Sea Otter | California Sea Lion | Harbor Seal | Brown Pelican | Murre |
|---|---|---|---|---|---|
| BRAIN | | | | | |
| Sample Size | 16 | 3 | 2 | 13 | 22 |
| Range | 0.10 - 34 | 38 - 74 | 0.67 - 1.6 | 0.26 - 160 | 0.26 - 64 |
| Mean | 5.3 | 51 | 1.1 | 48 | 15 |
| FAT | | | | | |
| Sample Size | 7 | 2 | 4 | 1 | |
| Range | 0.41 - 36 | 400 - 720 | 8.0 - 160 | 26 | |
| Mean | 11 | 560 | 48 | 26 | |
| KIDNEY | | | | | |
| Sample Size | 19 | 4 | 7 | | |
| Range | 0.0069 - 12 | 4.4 - 32 | 0.02 - 0.10 | | |
| Mean | 4.5 | 11 | 0.06 | | |
| LIVER | | | | | |
| Sample Size | 23 | 3 | 9 | 1 | |
| Range | 0.032 - 15 | 6.0 - 12 | ND - 3.0 | 75 | |
| Mean | 2.7 | 8.4 | 0.79 | 75 | |
| MUSCLE | | | | | |
| Sample Size | 2 | 1 | 2 | 7 | 18 |
| Range | 1.8 - 12 | 2.7 | 0.08 - 0.58 | 2.7 - 330 | 0.16 - 7.1 |
| Mean | 7.0 | 2.7 | 0.33 | 88 | 1.8 |

ND = Not detected.

Date are from Shaw (1971) and Jack Linn, California Department of Fish and Game, Pesticide Laboratory (pers. comm.).

TABLE 9. Levels (ppm wet weight) of Several Trace and Major Elements in Sea Otter Tissues.*

| | Ag | Cd | Hg | Cu | Zn | Fe | Mn | K | Na | Mg | Ca | Sr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIDNEY† | | | | | | | | | | | | |
| Female { Range | | 0.21–165.57 | 0.03–3.93 | 3.4–12.6 | 21.9–67.4 | 64–212 | 0.57–1.57 | 1230–2360 | 1360–4960 | 91–574 | 33–486 | 0.21–6.66 |
| Female { Mean | | 42.13 | 0.79 | 7.9 | 41.2 | 117 | 0.96 | 1670 | 2100 | 217 | 139 | 1.45 |
| Male { Range | | 0.18–70.73 | 0.04–5.70 | 2.9–23.1 | 19.6–69.4 | 56–233 | 0.74–1.74 | 1180–2790 | 1250–3150 | 125–559 | 62–2080 | 0.27–19.79 |
| Male { Mean | | 24.14 | 1.53 | 8.1 | 38.9 | 141 | 1.08 | 1820 | 1870 | 272 | 303 | 2.39 |
| LIVER† | | | | | | | | | | | | |
| Female { Range | 0.04–2.64 | 0.06–107.37 | 0.11–8.11 | 3.4–116.7 | 32.7–104.9 | 92–1012 | 0.79–9.17 | 830–2230 | 1190–6220 | 139–936 | 26–940 | 0.15–3.60 |
| Female { Mean | 1.19 | 20.57 | 2.18 | 43.5 | 59.6 | 337 | 4.56 | 1560 | 2000 | 296 | 237 | 1.13 |
| Male { Range | ND‡–1.75 | ND–24.53 | 0.11–8.83 | 16.8–60.9 | 31.0–72.0 | 59–1983 | 0.90–9.06 | 890–2440 | 1160–3720 | 87–566 | 44–931 | 0.26–7.28 |
| Male { Mean | 0.47 | 9.56 | 3.91 | 37.4 | 50.9 | 461 | 3.23 | 1480 | 1920 | 255 | 228 | 1.45 |
| MUSCLE† | | | | | | | | | | | | |
| Female { Range | | ND–3.02 | 0.04–0.80 | 1.5–4.2 | 37.1–76.4 | 68–233 | 0.06–0.30 | 1140–3420 | 570–7500 | 139–530 | 21–368 | 0.28–1.79 |
| Female { Mean | | 0.66 | 0.30 | 2.42 | 50.1 | 133 | 0.17 | 2420 | 1900 | 236 | 118 | 0.69 |
| Male { Range | | ND–1.34 | 0.01–1.62 | 1.1–6.4 | 22.4–74.9 | 59–278 | 0.02–0.32 | 1260–3300 | 820–4830 | 124–445 | 38–259 | 0.35–2.93 |
| Male { Mean | | 0.37 | 0.49 | 2.5 | 42.2 | 129 | 0.18 | 1970 | 1870 | 238 | 115 | 0.97 |

* Data provided by John Martin, Moss Landing Marine Laboratories, Moss Landing, California, working under E.P.A. Grant No. R802350.

† Sample size: Kidneys, 18 females, 23 males; Liver, 18 females, 24 males; Muscle, 9 females, 15 males.

‡ ND = Not detected.

have relatively high levels of cadmium (Cd) while sea lions apparently have more of a tendency to concentrate mercury (Hg) (John Martin, pers. commun.).

Levels of Cd and Hg in sea otter tissues determined by the Department's Laboratory fall within the range in Table 9. Departmental testing for lead (Pb) in sea otter tissues has generally produced levels of less than 1.0 ppm (Jack Linn, pers. commun.).

Parasites. External parasites have been found to be extremely rare on sea otters in the wild. Light infestations of the nasal mite, *Halarachne miroungae*, on sea otters were considered fortuitous by Kenyon (1969), who also reported a massive infection of nasal mites in a captive female which was held in a fresh water pool for several years. We have not examined sea otters for nasal mites to any extent in California. Five sea otter pelts from California were examined at Pennsylvania State University for external parasites during 1972 and 1973. No external parasites of any kind were found on these pelts (Ke Chung Kim, pers. commun.).

A variety of internal parasites have been recorded for sea otters in northern populations, including trematodes, cestodes, nematodes and acanthocephalan worms in various internal tissues (Rausch, 1953; Kenyon, 1969).

Acanthocephalan parasites have been found to be very common in the intestines of sea otters in California (Hennesy, 1972). Hennesy identified four species of acanthocephalans of which *Corynosoma macrosomum* was by far the most common. The three other species, *Falsifilicollis altmani*, *F. kenti*, and *F. major* were quite rare. Parasite loads in the 31 otters he examined ranged from none to 511 worms and were, in general, higher for females. The highest count in a male was 100.

We have occasionally observed even higher acanthocephalan loads, presumably *Corynosoma*, in sea otter intestines in both males and females. The load often appears the heaviest in about the third to sixth meter (5 to 18 ft) of the intestine, which is about 9 to 11 m (approximately 30 to 36 ft) in the sea otter. One subadult female we examined had an infestation estimated to be in excess of 3,000 worms with at least 2,500 in the third to fifth meter of intestine. The level at which the parasite load becomes detrimental to a sea otter is probably not known, but it would seem that high loads must have some adverse effect on an animal. One female we recently necropsied had the intestinal wall perforated by these worms with resultant peritonitis, which probably contributed to the demise of the animal. The total load in this animal was 196 worms.

Eight sea otters chosen at random from 150 harvested in the spring of 1962 at Amchitka had a total of 271 *Corynosoma* sp. with a range of 1 to 98 individuals (Kenyon, 1969). These otters, we presume, were mainly healthy animals. Although Kenyon did not mention loads of these parasites during winter-spring die-offs at Amchitka, it seems probable that animals with large infestations would be more likely to succumb during a period

of environmental stress than animals with fewer of these parasites. The relationship between age and parasite load also bears further investigation.

## Ecological Studies

### Habitat Surveys

Both intertidal and underwater studies have been conducted throughout the sea otter's range to provide information on ecological relationships between sea otters and their environment.

Seven permanent intertidal stations were established and the biotic assemblages were surveyed. Three stations were surveyed between Cambria and Point Estero (two of which were established prior to the influx of sea otters into the area), one near Point Piedras Blancas, one near Point Sur, one in the vicinity of Pacific Grove and one in Point Lobos State Reserve.

Two stations located in the Cambria to Point Estero area were resurveyed and appeared to show evidence of sea otter foraging. These two stations, 30 m by 2 m (98 ft by 7 ft) in size, were located where public access is not permitted and human use is insignificant. Apparent sea otter foraging is evidenced by a reduction in numbers of black abalones and their restriction to protected habitat. Between 1969, when sea otters were first moving into this area, and 1971 there was a reduction in black abalones by 28% (162 to 117) at one station, while at the other there was a reduction of 31% (285 to 179). Initially many black abalones were observed in exposed areas, while the last survey revealed few remaining in open habitat. In addition, food habits observations in the vicinity have shown black abalones in the sea otter's diet.

Resurveys of stations near Point Sur and Point Piedras Blancas, well within the established range of sea otters, showed few biotic changes from the initial survey conducted in 1969.

Numerous random underwater surveys, including both measured transects and general habitat reconnaissance dives, have been made throughout the sea otter's range to measure the relative abundance of sea otter forage items. Wherever sea otters feed in significant numbers, preferred forage items such as abalones, sea urchins, and crabs become depleted and limited to rocky crevices and other protected habitat as was described by Ebert (1968b), except that this pattern of depletion now extends into habitat more recently occupied by sea otters.

Underwater reconnaissance surveys in late 1970 in the vicinity of Santa Cruz to Ano Nuevo indicated that the forage items and kelp bed habitat available would support a sea otter population expansion in this area.

Food Habits Studies

Observations of foraging sea otters in California have been reported upon by a number of observers including Fisher (1939); Limbaugh (1961); Hall and Schaller (1964); Boolootian (State of California. Senate Fact Finding Committee on Natural Resources, Subcommittee on Sea Otters. Affect of the Sea Otter on the Abalone Resource. Transcript of Hearing, San Luis Obispo, November 19, 1963.); Ebert (1968a); and Vandevere (1969). These studies vary considerably in the reported composition of food items in the sea otter's diet since they were done in different areas at different times and where sea otters had been established for varying lengths of time.

Ebert compared food habits observations by Fisher, Hall and Schaller, and Boolootian with his studies at Pico Creek, where sea otters had recently become permanently established. Ebert concluded that availability and preference of food items determined, to a large extent, the composition of the sea otter's diet. Ebert's analysis also indicates that when sea urchins, abalones and rock crabs are available in abundance, which occurs only in areas newly colonized by sea otters, they will constitute a major percentage of the otter's diet; furthermore, he demonstrated that populations of these invertebrates, especially red sea urchins and abalones, become significantly reduced with continued sea otter foraging, and sea otters exert a considerable impact on these resources used by man.

Vandevere observed sea otter food habits in three different areas in 1969, one of which was a newly colonized area near Cambria. In the Cambria area, Vandevere reported only abalones and crabs in the otter's diet, with abalones accounting for 88%. In the other two areas, where otters had been established for many years, the diet was more diverse and abalones were considerably less significant (5.1% at Pt. Lobos near Carmel and 25% at Lopez Point). Since Vandevere did not include unidentified items, the actual percentages would be even lower. As much as 57% of the food items at Lopez Point were unidentified (Vandevere, pers. commun.).

These previous studies, collectively, indicate that sea otters in California utilize a wide variety of nearshore marine invertebrates consisting primarily of molluscs, echinoderms and crustaceans, and that algae and fishes have been insignificant in the diet. These studies also indicate that sea urchins, abalones and crabs when available in abundance will be heavily foraged upon by sea otters. In addition, it appears that a shift to lower percentages of preferred food items and an increase in diversity occurs after otters have become established in an area for some time. This is apparently due to reduced populations of preferred forage items.

We observed sea otter feeding behavior to provide additional information on the relationship of sea otters to the nearshore marine environment, especially as they become permanently established in new areas and to evaluate further the impact of sea otter foraging on resources utilized by man by comparing food habits observations as otters initially became established in new areas with observations after they had been there some time.

Our food habits studies were concentrated at the southern end of the sea otter's range where the population has continued to expand into areas of significant sport and commercial abalone fisheries and, more recently, into the vicinity of a developing red sea urchin fishery.

From 1971 to 1973 we observed foraging sea otters at Pico Creek; in the vicinity of Point Estero; at Cayucos Point; Atascadero State Beach; and Point Buchon. We chose these areas because they represented the southern end of the sea otter's range when the observations were made, or because we could compare our observations with data collected when an area previously represented the southern end of the range. Observations at Atascadero State Beach were made in early 1973 when the population was extending its range from Cayucos to Point Buchon.

Observations were made from shore using a telescope ranging from 15x to 60x. Food items were identified to the lowest taxon possible and recorded in the field. Food items were sometimes identified only to rather general categories because precise field identifications were not possible. Such items, in some cases, were probably the same as those for which a more precise category was present. For example, unidentified abalones were most likely red or black abalones (*Haliotis rufescens* and *H. cracherodii*), although they could have been other smaller species much less common in the area, such as the pinto, *H. kamtschatkana*, or the flat, *H. wallallensis*. Some food items, particularly small ones, could not be identified at all, and were recorded as unidentified items.

Two similar species of crabs of the genus *Cancer* (rock crab, *C. antennarius*, and red crab, *C. productus*) occur in the areas studied. Rock crabs are by far the most common in these areas. Although no red crabs were identified in our observations, it is possible that an occasional red crab was being eaten.

Percentages of food items by number were calculated for ease of comparison with other studies. However, percentage of a food item by number in the diet bears little relationship to percentage by volume. For example, 15% abalones observed in the diet would equal many times the food volume of 15% tegulas (small snails). A comparison of food volumes from several different sea otter food items was calculated by Ebert (1968a) (Appendix I).

Pico Creek. Pico Creek is situated about halfway between Point San Simeon and Cambria in San Luis Obispo County (Figure 2). A broad area surrounding Pico Creek (Fish and Game District 118) has been closed to commercial abalone fishing from 1937 to the present, except for the period from 1955 to 1957 (California Fish and Game Code, 1937 and 1955). Prior to 1966 abalones were generally considered to be abundant throughout the area (Earl Ebert, pers. commun.). Ebert (1968a) studied the diet of sea otters near Pico Creek in 1966 about 5 months after a large rafting group had been first observed in the area; we studied the same area about 5 years later (Table 10). Although Ebert's study began

TABLE 10. Sea Otter Food Items Observed Near Pico Creek from April 21 to June 2, 1966, (from Ebert, 1968a) and from March 29 to August 25, 1971.

| | 1966 | | 1971 | |
|---|---|---|---|---|
| Approximate time observing feeding | 35 hours | | 16 hours | |
| Approximate time otters permanently established in area prior to study | 5 months | | 5 years | |
| FOOD ITEMS | NUMBERS | PERCENT | NUMBERS | PERCENT |
| Black abalone, *Haliotis cracherodii* | | | 1 | 1.0 |
| Red abalone, *Haliotis rufescens* | 154 | 63.4 | 4 | 3.8 |
| Unidentified abalone, *Haliotis* sp. | | | 1 | 1.0 |
| Tegula snails, *Tegula* spp. | | | 25 | 23.8 |
| Gumboot chiton, *Cryptochiton stelleri* | 1 | 0.4 | | |
| California mussel, *Mytilus californianus* | 2 | 0.8 | | |
| Rock scallop, *Hinnites multirugosus* | 5 | 2.1 | | |
| Gaper clam, *Tresus nuttallii* | 6 | 2.5 | | |
| Kelp crab, *Pugettia producta* | | | 8 | 7.6 |
| Rock crab, *Cancer antennarius** | 63 | 25.9 | 33 | 31.4 |
| Unidentified seastars | | | 4 | 3.8 |
| Bull kelp, *Nereocystis luetkeana* | | | 1 | 1.0 |
| Giant kelp, *Macrocystis* sp. | 3 | 1.2 | 1 | 1.0 |
| Unidentified kelps | | | 12 | 11.4 |
| Unidentified items | 9 | 3.7 | 15 | 14.3 |
| TOTALS | 243 | 100.0 | 105 | 100.1 |

* May include an occasional red crab, *Cancer productus*.

shortly after sea otters apparently became permanently established in the area, there had been intermittent reports of a few individuals in the area occasionally for several years (Bissell and Hubbard, 1968).

The most significant difference in the sea otter's diet at Pico Creek was the drastic decline of red abalones in the diet (63% in 1966 to less than 5% in 1971) and the appearance and relative importance of other items such as tegulas, kelp crabs and sea stars in 1971.

Rock crabs comprised about the same percent in both studies. Ebert (pers. commun.) reports that many of the rock crabs he observed being eaten were gravid females. Ebert noted that otters did not eat the crab eggs and recalls seeing these egg masses among the bottom litter during reconnaissance dives of the area. In 1971, gravid female rock crabs were again noted, but this time at least some of the egg masses were eaten along with the crabs.

Red sea urchins were not observed being eaten in either study, although Ebert's underwater inspections attested to their former abundance and the probable foraging upon them by sea otters.

Kelps (large brown algae) were observed eaten much more commonly in 1971 than in 1966, although Barabash-Nikiforov (1947) and Kenyon (1969) report that algae pass through a sea otter's digestive tract undigested. It is possible that otters are eating small attached invertebrates when ingesting algae.

The observed diet was apparently more diverse in 1971 than it was in 1966. In 1966 only two items, red abalones and rock crabs, comprised nearly 90% of the observed food items, while the four largest categories of identified food items in 1971 amounted to only 74%. A slightly greater number of identified items was observed in 1971 in less than half the time. The percentage of unidentified items was nearly four times greater in 1971 and probably included more species.

Point Estero. The nearshore area from Cambria to Point Estero (Figure 2) was long known as the "Point Estero beds" to commercial abalone divers. The area supported commercial abalone harvesting for many years (see Appendix I). Otters permanently moved into the northern portion of this area in 1967 and in 1969 had established their range to Point Estero.

We first observed food habits in the southern portion of this area in 1971, about 2 years after otters had become permanently established, and we made brief observations there again in 1972, about 1-1/2 years later (Table 11).

Abalones declined from over 70% observed in the diet in 1971 to less than 4% in 1972. Vandevere (1969) had observed the sea otter's diet in the northern portion of the Cambria-Point Estero area in 1969 and noted that 88% of the items seen eaten at that time were abalones. However, since

TABLE 11. Sea Otter Food Items Observed from 1 to 4 Miles North of Point Estero between March 3 and October 25, 1971, and between August 24 and October 25, 1972.

| | 1971 | | 1972 | |
|---|---|---|---|---|
| Approximate time observing feeding | 27 hours | | 5 hours | |
| Approximate time otters permanently established in area prior to study | 2 years | | 3-1/2 years | |
| FOOD ITEMS | NUMBERS | PERCENT | NUMBERS | PERCENT |
| Black abalone, *Haliotis cracherodii* | 9 | 11.0 | 1 | 1.9 |
| Red abalone, *Haliotis rufescens* | 48 | 58.5 | 1 | 1.9 |
| Unidentified abalones, *Haliotis* spp. | 2 | 2.4 | | |
| Tegula snails, *Tegula* spp. | 4 | 4.9 | 23 | 44.2 |
| Kelp crab, *Pugettia producta* | 4 | 4.9 | | |
| Rock crab, *Cancer antennarius** | 3 | 3.7 | 9 | 17.3 |
| Unidentified crabs | | | 2 | 3.8 |
| Red alga | | | 1 | 1.9 |
| Unidentified items | 12 | 14.6 | 15 | 28.8 |
| TOTALS | 82 | 100.0 | 52 | 99.8 |

*May include an occasional red crab, *Cancer productus*.

Vandevere did not differentiate between species and did not include unidentified items in his data, they are not directly comparable with ours. The actual percentages in his observations would be somewhat less if unidentified items were included. Nevertheless, observations in the Cambria - Point Estero area indicate a significant decline of abalones in the diet by 1972. Furthermore, a series of diving surveys from 1967 to 1973 indicates that a decline in red abalones of all sizes (not just commercial legals) occurred after sea otters moved into the area and commercial divers abandoned the "Point Estero beds" in 1971 (Burge, 1973).

Sea urchins were not observed in any of the studies in this area. However, an extensive diving survey in 1967 documents their former abundance in the area (Ebert, 1968b). Sea Otter Project diving surveys in 1969 indicated the presence of sea urchin litter on the sea floor apparently from sea otter foraging.

In 1972, the observed diet shifted significantly to tegulas, rock crabs and unidentified items. The increase in rock crabs in 1972 is probably more apparent than actual. Since rock crabs are quite mobile, generally cryptic in habit, and may see a predator coming, more of them are apt to escape predation, especially when abundant forage is available in the open. As other forage becomes less available, sea otters tend to roll large rocks and forage deeper in crevices, etc., and more crabs are apt to be taken. Also, a major portion of the sea otters at Point Estero had moved on to Cayucos Point in early 1972 and this left fewer sea otters apparently feeding on more crabs when an actual decline in the crab population was obvious from diving surveys (Burge, 1973).

An increase in diversity in the diet in 1972 is apparent from the increase in the numbers of species (tegulas, rock crabs and unidentified items) making up a major portion of the diet and the significant number of unidentified items (nearly 30%) observed during the small amount of time spent observing.

Cayucos Point. Cayucos Point is located at the northern end of Estero Bay. The rocky reefs and kelp beds in the vicinity of Cayucos Point represent the last habitat of this type from Cayucos to the Point Buchon area, a distance of about 23 km (14 miles), characterized mostly by sandy bottom habitat offshore and sandy beaches along the shoreline.

The rocky reefs in the Cayucos Point area are mostly shallower than 6 m (20 ft). Since commercial abalone fishing is prohibited in waters shallower than 6 m (20 ft) along the California coast, this area never supported much of a commercial abalone fishery.

A sport abalone fishery existed in the area and continued to do so through at least early 1972 (Daniel Miller, pers. commun.).

Our observations began about 3 months after a large rafting group of sea otters was observed at Cayucos Point in early 1972 and continued intermittently for about 8 months (Table 12). Abalones were the most

TABLE 12. Sea Otter Food Items Observed Near Cayucos Point Between May 20, 1972, and January 24, 1973.

| | |
|---|---|
| Approximate time observing feeding | 44 hours |
| Approximate time otters permanently established in area prior to study | 3 months |

| FOOD ITEMS | NUMBERS | PERCENT |
|---|---|---|
| Black abalone, *Haliotis cracherodii* | 2 | 0.6 |
| Red abalone, *Haliotis rufescens* | 160 | 47.1 |
| Unidentified abalone, *Haliotis* sp. | 1 | 0.3 |
| Tegula snails, *Tegula* spp. | 51* | 15.0 |
| Gaper clam, *Tresus nuttallii* | 12 | 3.5 |
| Littleneck clams, *Protothaca* spp. | 5 | 1.5 |
| Unidentified clams | 3 | 0.9 |
| Octopus, *Octopus* sp. | 1 | 0.3 |
| Kelp crab, *Pugettia producta* | 13 | 3.9 |
| Rock crab, *Cancer antennarius*† | 37 | 10.9 |
| Unidentified crabs | 6 | 1.8 |
| Unidentified items | 48 | 14.2 |
| TOTALS | 339 | 100.0 |

* Number partially estimated.

† May include an occasional red crab, *Cancer productus*.

common item in the diet at Cayucos Point during our observations. We made reconnaissance dives at Cayucos and Cayucos Point in July 1972. At Cayucos, empty abalone shells, many with the characteristic sea otter break, provided evidence of otter foraging even though sport abalones were still available at that time. At Cayucos Point, about 1.6 km (1 mile) to the north, the abalone population was considerably depleted and more sea otter foraging litter consisting of abalone shells, crab debris and clam shells was apparent.

No sea urchins were observed being eaten at Cayucos Point during our observations. The occasional presence of a few foraging otters prior to the establishment of a large rafting group in this area of limited habitat could account for the absence of sea urchins in our observations.

The variety in the diet in this recently colonized area may be due to the long period during which observations were made, the presence of food items from both rocky reef and sandy habitat and the large number of sea otters which eventually occupied this area of limited habitat. We observed a maximum of 207 sea otters in the vicinity of Cayucos Point in December 1972. In early 1973, sea otters were observed to have extended their range nearly 23 km (14 miles) to the south, where at least 57 were seen in the vicinity of Point Buchon in February of that year.

Atascadero State Beach. Brief observations were made at Atascadero State Beach just north of Morro Bay during February and March 1973 when sea otters were becoming established near Point Buchon. During about 3 hours of observations, 29 food items were observed being eaten by sea otters. All but two (which were unidentified) were Pismo clams, *Tivela stultorum*. On one occasion a single otter was observed to eat 22 Pismo clams in 2 hours.

Otters are seldom, if ever, observed in mass over sandy areas and have not been reported to raft in groups in these areas in California. The extent and effect of otters foraging in sandy bottom areas is unknown, although several foraging individuals are not uncommon in sandy areas near large rafting groups.

Point Buchon. The area just to the north of Point Buchon is the first rocky reef - kelp bed habitat south of Cayucos. This area has supported a significant sport abalone fishery, and an estimated 9 thousand sport abalone were taken there in 1972 (Daniel Miller, pers. commun.). The area has never been a popular commercial abalone spot, although some commercial red abalone landings have come from there. However, the area from south of Point Buchon to Avila supports the major remnant of the dwindling Morro Bay commercial red abalone fishery. The Point Buchon area reportedly has been a high density sea urchin area and a small commercial sea urchin fishery has been developing in the general area recently.

In January 1973 a large group of sea otters was first observed in the area just north of Point Buchon. In early February 1973 we counted 57 sea otters there, and by April as many as 137 were observed in the area. Our

observations began within 2 weeks of the first sightings of a large group of sea otters in the area (Table 13).

Although individual otters had been reported occasionally as far south as Shell Beach in recent years, there apparently had been very little impact by sea otters at Point Buchon before the large group appeared in early 1973. During our observations, red sea urchins were being eaten in abundance, accounting for nearly half of all food items. Red sea urchins, abalones and rock crabs accounted for over 90% of the diet during the period of our observations.

The individual preference of some animals seems to affect the diet at times, since California mussels were observed being eaten on only 1 day.

A relatively low diversity of food items was apparent from the few items comprising a major portion of the diet and the low incidence of unidentified items. We expect that the diet will become more diverse in this area as sea urchins, abalones and crabs become depleted with continued sea otter foraging.

Food Habits Discussion. The food habits studies we reviewed combined with our observations indicate that sea otters in California feed on a wide variety of marine invertebrates, infrequently on fish, and occasionally are observed to ingest algae. These studies also indicate that the composition of the diet will vary considerably according to availability and abundance of forage species, sea otters' preferences, and the number of otters present and length of time they have been established in an area.

Sea otters' feeding preferences have been most apparent when they first become established in new areas where a wide variety of marine invertebrates are readily available and abundant. Ebert (1968a) concluded from his diving observations at Pico Creek that "abalones, rock crabs, rock scallops and gaper clams were utilized relative to their availability and these items, therefore, were preferred over mussels, sea stars, and chitons." A diving survey throughout the sea otter's range in 1967 indicated that the gumboot chiton, *Cryptochiton stelleri*, and spider crab, *Loxorhynchus grandis*, both relatively large, potential sea otter food items, were readily available and the chiton was quite abundant (Ebert, 1968b). Neither are observed being eaten often by sea otters. A variety of sea stars are relatively abundant along the California coast and throughout the sea otter's range. These are apparently only eaten when preferred sea otter food items are depleted and then, may not make up a significant portion of the diet.

Our studies indicate that red sea urchins, red abalones, and rock crabs are preferred food items in the sea otter's present range in California. In addition, Pismo clams may be eaten almost exclusively when sea otters are foraging in sandy areas where these are abundant. Even though red sea urchins, when available, become depleted first, an order of preference is not easy to establish since sea urchins are probably the easiest to obtain and crabs, having eyes and being quite mobile, may escape predation more easily than

TABLE 13. Sea Otter Food Items Observed from 1/4 Mile to 1 Mile North of Point Buchon Between January 30, 1973, and April 13, 1973.

| | |
|---|---|
| Approximate time observing feeding | 24 hours |
| Approximate time otters permanently established in area prior to study | 2 weeks |

| FOOD ITEMS | NUMBERS | PERCENT |
|---|---|---|
| Black abalone, *Haliotis cracherodii* | 7 | 2.6 |
| Red abalone, *Haliotis rufescens* | 62 | 23.3 |
| Unidentified abalone, *Haliotis* sp. | 1 | 0.4 |
| California mussel, *Mytilus californianus* | 19 | 7.1 |
| Kelp crab, *Pugettia producta* | 2 | 0.8 |
| Rock crab, *Cancer antennarius** | 43 | 16.2 |
| Unidentified crab | 1 | 0.4 |
| Red sea urchin, *Strongylocentrotus franciscanus* | 130† | 48.9 |
| Unidentified item | 1 | 0.4 |
| TOTALS | 266 | 100.1 |

* May include an occasional red crab, *Cancer productus*.

† Includes 22 urchins identified from gonads only.

either sea urchins or abalones. The extent of the effect of sea otter foraging on clams, particularly the Pismo clam, is not yet known. However, our observations near Morro Bay indicate that it could be considerable, as sea otters become established in areas adjacent to significant clam populations. Nevertheless, preferred forage species such as sea urchins, abalones and crabs become depleted where sea otters become established in new areas and the diet shifts to a wider variety of food items.

The depletion of preferred forage items has been noted by several observers. Ebert (1968a) states that:

"Department biologists tagged more than 400 red abalones at Stillwater Cove, near Monterey, in July 1956. The following June they returned to the same area but could not locate tagged abalones. Divers traversed more than 1/2 mile of bottom but found only one red abalone about 6 inches long deep in a crevice. Empty abalone shells and sea urchin fragments littered the substratum. In this same area, Department biologists recovered, tagged, and replaced more than 100 abalones per day during a 4-day period the preceding year. Department records indicate that the depletion of abalones at Stillwater Cove correlates with the arrival of sea otters in late 1956."

McLean (1962) conducting an ecological study by scuba in kelp beds about 16 km (10 miles) south of Carmel noted that red sea urchins were "totally absent although spines and test fragments were present in gravel samples" and red abalones were uncommon and restricted to protected crevices. He concluded that this was due to sea otter predation.

Faro (1969) observed subtidal sea otter habitat by scuba at Point Pinos about 5 years after sea otters had become established there. He reports that red sea urchins and red and black abalones were considerably less abundant than in comparable areas without sea otters and were generally found only in crevices and under rocks. Faro concluded that this was due to sea otter foraging. He states that "Prior to the re-establishment of sea otters, the area was nicknamed 'the meat locker' by local (sport) divers because red abalones were easily available."

Minter (1971) conducted operations by scuba off Del Monte Beach near the Monterey-Seaside border after sea otters had been in the area for at least 3 years. Minter states that "Numerous shells of the red abalone were observed littering the bottom, yet not a single living animal (abalone) was seen." In addition, Minter reports that he saw no living specimens of red or purple sea urchins and the few rock crabs which he saw were usually small.

A significant sport rock crab fishery which existed on the Monterey wharf nearby has virtually ceased in recent years while sport rock crab fishing presently continues to flourish at Santa Cruz where there yet has been little impact from sea otters (Daniel Miller, pers. commun.). A commercial red and rock crab fishery is presently conducted in the Avila area just south of the current southern end of the sea otter's range.

Burge (1973) documents a depletion of red sea urchins, red abalones and rock crabs in the Cambria-Point Estero area between 1967 and 1973. Sea otters first moved into the northern portion of this area in 1967 and by 1969 had established their range to Point Estero. Commercial divers abandoned all of the Cambria-Point Estero beds in 1971.

Our recent studies (Tables 10-13) provide additional documentation of heavy foraging upon and subsequent depletion of preferred sea otter forage items as sea otters have become established in new areas.

The impact of sea otters on resources has been the same in an area near Pico Creek, which except for a brief period was closed to commercial abalone fishing, as it was where extensive commercial abalone fishing had occurred for years. The impact has also been similar on sea urchins and rock crabs which have not been subjected to sport or commercial use throughout much of the otter's range. Therefore, the loss of commercial and sport fisheries for abalones and crabs where these have occurred within the sea otter's range can be attributed solely to the foraging habits of sea otters.

The depletion of less preferred food resources also occurs the longer sea otters inhabit an area. Faro (1969) noted a definite reduction in California mussels, *Mytilus californianus*, at Point Pinos. Donald Abbott, Associate Director, Hopkins Marine Station, Pacific Grove (pers. commun.), reports that extensive California mussel beds existed on the nearshore rocks in the marine station reserve at least until August 1968. These mussel beds were reportedly "8 to 12 inches thick with individuals up to 6 inches long." By March 1969 these beds had been so depleted by sea otter foraging that it was nearly impossible to find a suitable area to conduct a planned research project on mussels. Other invertebrates are also reportedly reduced in numbers in this area. It is quite evident that sea otter foraging has resulted in a reduction of mussels and other invertebrates on pilings along Monterey's Cannery Row and on floats and pilings in the Monterey Marina.

Sea otters' food intake requirements, their potential and actual impact on resources used by man and the loss of sport and commercial abalone fisheries in the sea otter's range are thoroughly documented in Appendix I.

With continued expansion of the sea otter's range we can expect further resource conflicts with the remaining red and black abalone and red and rock crab fisheries along the California coast. The recently developed sea urchin fishery in the Point Buchon - Avila area soon will be lost. Furthermore, sea otters can be expected to forage heavily upon pink and green abalones, *H. corrugata*, and *H. fulgens*, Pismo and other clams, market and yellow crabs, *Cancer magister* and *C. anthonyi*, and in all probability, spiny lobsters, *Panulirus interruptus*, and possibly upon oysters in oyster farms, when they come in contact with these resources along the California coast.

## Studies on Otters in Captivity

Kenyon (1969) reports that the sea otter is highly adaptable to life in captivity when its environmental and food needs are met. Considerable experience has been gained in maintaining sea otters in captivity in Alaska. Successful long-term sustenance of sea otters from Amchitka has been achieved at Woodland Park and Point Defiance Zoos in Washington State.

Initially in our operations, scientific studies were conducted on two captive sea otters, by special agreement with Stanford Research Institute's Biological Sonar Laboratory, to learn techniques of medical care and husbandry of otters and for tagging experiments. The sea otters were delivered to S. R. I. in March 1969 and were maintained in captivity for nearly 8 months, whereupon their condition deteriorated rapidly and the animals died on October 30 and 31, 1969. Necropsies conducted on these animals revealed gastroenteritis with dehydration and subsequent cardiovascular failure. Enteritis is frequently observed as the terminal symptom at death of sea otters in the wild on Amchitka (Kenyon, 1969). This condition has also been observed during necropsies on carcasses of wild otters in California. Stullken and Kirkpatrick (1955) indicate that captivity mortality in sea otters at Amchitka was probably due to acute stress or shock reaction characterized by rapidly developing gastroenteritis. The factors contributing to the terminal symptoms in our captive otters are not known. More information and experience are needed in maintaining otters in captivity.

A special agreement was completed with Sea World in San Diego in late 1972 to place sea otters in captivity there for additional scientific studies.

On December 11 and 12, 1972, five sea otters (three females and two males) were captured with the diver-held capture device in the Monterey area, placed in specially designed cages and flown by DC3 airplane to San Diego, where they were transferred to Sea World by carryall.

The females, two subadults and an adult, which were captured on December 11 off Del Monte Beach near the Monterey-Seaside border, weighed 11.4, 13.6 and 18.2 kg (25, 30 and 40 lb). Veterinarian Peter Schroeder, associated with Sea World, assisted CDFG personnel with the capture and accompanied the senior author on the flight to San Diego. Five hours and 14 minutes elapsed from the placement of the first captured female into a cage on the boat until all three were released into the pool at Sea World. All appeared in excellent condition and within 2 hours were eating red and purple sea urchins, crabs (*Cancer* spp.) and abalone trimmings which had been tossed into the pool.

The next day, the two males, a subadult and an adult, weighing 16.5 and 25.0 kg (36 and 53 lb) were captured off Monterey's Cannery Row. John Sweeney, Sea World veterinarian, assisted with these capture operations and accompanied the senior author on the flight to Sea World. This transfer was accomplished in 4 hours and 31 minutes from the placement of the smaller

male into a cage on the boat until both males were released into the pool at Sea World. After the introduction of the males into the pool, crabs and abalone trimmings were offered. The females began feeding almost immediately and within 1/2 hour both males were actively feeding. The males appeared to adapt to their surroundings more readily than had the females, probably due to the presence of the females. Nevertheless, by the next day, it appeared that the smaller male was not adapting as well as the others.

It soon became obvious that this animal was wet to the skin, particularly around the hind quarters. After a couple of days the animal exhibited shivering symptoms at times. The animal's fur probably became disturbed on the trip down, most likely from fecal matter in the cage. Water apparently penetrated to the skin when the animal was released into the pool. It hauled out on a float occasionally and attempts were made to dry the fur with heat lamps and a hair dryer during the next few days. The fur was never completely dried out and when the animal re-entered the water to swim or feed it became soaked again. It was important to feed the animal primarily in the water since feeding out of the water tended to soil the fur more from the food residues. Sea otters often roll frequently in the water when feeding, presumably to wash off food residues.

During the first few days, the animal's condition worsened and the animal became comatose and died on December 16, 1972. Its death was apparently due to stress associated with exposure and eventually a lowered body temperature. The intestine had 257 acanthocephalan worms, presumably *Corynosoma* sp.

The other four animals have adapted very well to captivity. Since their introduction the otters have been offered about 27 kg to 36 kg (60 to 80 lb) of food daily, usually distributed over three feedings a day. They usually appear to consume most of it. The diet has consisted mainly of frozen eastern clams and frozen crabs (*Cancer* spp.). At times it has been supplemented with live abalones, frozen abalone trimmings and squid (James Antrim, pers. commun.).

The enclosure consists of a 70 thousand gallon salt water pool in which the water is completely filtered about every 2 hours with about 25% fresh sea water added. A smaller tank (11 thousand gal) is connected by a short passageway for easy diversion of the animals for tank cleaning or other activities requiring movement out of the main pool. A sun filtering shade is suspended well up over the pool, which is otherwise open around the periphery to allow for free air circulation.

A public viewing area constructed to minimize sounds and equipped with one-way glass provides for minimal human disturbance of the animals.

Arrangements for commencing with research on food preference studies under Sea World's direction were being finalized with the Department at the time of this writing.

Other studies which may be considered in the future include various aspects of physiology, behavior, underwater phonations and reactions to various sounds, visual acuity, metabolism, reproduction, parasites and microbiological flora.

## SUMMARY AND CONCLUSIONS

Emphasis in the early phase of the Sea Otter Research Project was directed toward development of trapping and tagging gear and gaining experience in handling sea otters. Initial capturing efforts utilized gill nets which worked well but resulted in a few sea otter drownings. Mortality levels due to trapping during early project activities had no adverse effects on the sea otter population. However, these activities were curtailed and efforts were redirected to developing a safe, efficient capture technique. The result was a diver-held capture device which has eliminated capture mortality.

Fifty-eight sea otters were captured during the 5 years of this study, 29 with gill nets and 29 with the diver-held capture device. Seventeen were translocated within the range, tagged and released; 29 were tagged and released on site; 8 were placed in captivity; 4 drowned in the nets.

In all, 23 sea otters were removed from the Cambria-Point Estero area by translocation, placing otters in captivity and capture mortality. The removal of otters from this area, designed to provide some relief to the commercial abalone fishery was unsuccessful due to the return of some translocated otters and the continued natural influx of additional otters into the area. As the sea otter population continued to extend its range to the south, the commercial abalone fishery north of Morro Bay completely collapsed. Sea otters foraged so heavily on abalones in this area that by 1971 abalone divers abandoned the last of the historically abundant abalone beds north of Point Estero that had supported an annual commercial harvest for many years. The sport abalone fishery within the sea otter's range from Monterey to Cayucos has been similarly affected.

Translocation of otters outside the sea otter's range was investigated as a possible solution to resource use problems. Suitable sea otter habitat exists along much of the California coast. However, due to the extreme potential for additional resource use conflicts with a variety of resources wherever such habitat exists, translocation outside the present range is not a feasible solution to current problems.

Sonic barriers are not considered a feasible method to limit sea otter range expansion.

Aerial and surface censuses have revealed that the sea otter population is continuing to increase in numbers and expand its range. These censuses provide the basis for population estimates and density calculations. The sea otter population in mid-1973 was estimated at about 1,600 to 1,800 animals and ranged from Santa Cruz on the north to just beyond Point Buchon on the south.

The sea otter population, as a whole, apparently has been increasing at a faster rate than the segment within a major central portion of the range. The data indicate that the excess has been supporting range expansion with significantly greater densities of sea otters occurring at the extremes of the range.

Range expansion is apparently accomplished largely by accumulations of subadult and younger adult animals at the fringes of the range.

Capture data reveal that sea otters in California segregate by sex much as they do in populations in the north Pacific. The data suggest that males may have a larger home range than females, as is reported for northern populations, but more information is needed to establish home range in California.

Little information is available about sex and age groupings and movements throughout a major central portion of the range.

Sea otter carcasses have been recovered primarily toward the ends of the range. Cause of death in sea otters in California in recent years has been found to be due to a variety of human and natural causes. Human causes of sea otter deaths have included being hit by boats, shooting or spearing, and blows. Boating accidents appear to be the most common human caused mortality. Several animals were definitely shot in 1969 and 1970, but shooting has not been much of a problem since. Natural deaths occur from a variety of causes such as infection, trauma, starvation, etc. A significant increase in natural mortality occurred during the 1972-1973 winter-spring period. This was apparently associated with a relatively severe winter, combined with concentrations of animals in certain areas with resultant depletion of food supplies. A higher ratio of pups, subadults, and aged adults to adults was apparent in this die-off compared to prior years. Animals in these age groups are apparently less able to forage as efficiently under such conditions.

Sea otter carcass materials have been provided to a number of scientific and educational institutions for studies on taxonomy, anatomy and physiology, environmental contaminants such as pesticides, polychlorinated biphenyls and trace and major elements and studies of parasites.

Habitat studies within the sea otter's range reveal that sea otters exert a profound effect on the nearshore environment, particularly on biological community structures of nearshore invertebrates. Habitat studies adjacent to the sea otter's range indicate that these areas will support sea otter population expansion.

Food habits studies reveal considerable variation in the sea otter's diet depending on the location and the length of time otters have been in an area. In newly colonized areas where sea urchins, abalones and crabs are abundant, these have been observed to constitute a major portion of the diet. As these become depleted with continued foraging, the diet

becomes more diverse and less preferred forage items become more significant in the diet. Human utilization of many sea otter forage items virtually ceases in the presence of significant numbers of foraging otters as forage items become reduced in number and size and are restricted to rocky crevices and other protected habitat.

Successful long-term sustenance of sea otters in captivity in Washington State has demonstrated that sea otters can be successfully maintained in captivity. Early in our operations, two sea otters were maintained in captivity at Stanford Research Institute's Biological Sonar Laboratory for nearly 8 months for tagging and other studies. An opportunity to further our knowledge of the sea otter's behavior, food habits, physiology, medical care, etc., is now possible through captive studies being developed on four sea otters placed in captivity at Sea World, San Diego, in December 1972. This information should help to assure that a healthy sea otter population will be maintained off our coast.

Population dynamics data, habitat surveys, and food habits studies all indicate that the sea otter population in California is continuing to increase in numbers and expand its range. These studies also indicate that the sea otter is directly responsible for the loss of sport and commercial abalone and sport crab fisheries within the sea otter's range. If it were feasible to remove sea otters and prevent them from re-entering abalone beds, the now defunct abalone fishery north of Point Estero could most likely be returned to its former production level. If otters were removed from the Point Buchon area, the remaining sport and commercial red abalone fisheries, the developing sea urchin fishery and crab fisheries there could be saved.

However, if unrestricted expansion of sea otters is allowed to occur in California, additional sport and commercial resources currently being utilized by man will be adversely affected. Southward range expansion will bring otters into conflict with fisheries for pink and green abalones, Pismo and other clams, crabs and lobsters. Northward range expansion, already begun, will conflict with sport and commercial abalone and crab fisheries along the Santa Cruz - San Mateo coast and, eventually, abalone, crab, scallop and clam fisheries and possibly oyster farming on the north coast.

Since translocation of sea otters outside the present range in California would only compound the problems, the only practical way to provide for continued human utilization of resources foraged upon by sea otters and also maintain a healthy population of sea otters in California, is to manage a portion of the coast for sea otters and limit their range to that area and to continue to manage other coastal areas for human resource usage.

## RECOMMENDATIONS

Research has demonstrated that a variety of invertebrate resources used by man have been depleted by the foraging activities of an expanding

sea otter population. Continuing sea otter range expansion will result in a wider variety of resource uses being adversely affected.

Research has further demonstrated that two basic alternatives are available for maintaining the California sea otter resource:

1. Protection and management of a healthy sea otter population restricted within geographical limits along the California coast.

2. Protection of an unrestricted sea otter population along the California coast.

The Department believes that the recreational and commercial uses of our resources are important and beneficial and we cannot allow them to be destroyed by sea otters. Therefore, it is essential that the sea otter population be restricted within geographical limits.

Management and restriction of the sea otter population within its present range in California would provide protection for a variety of resource uses adjacent to the sea otter's range. Implementation of restriction would probably be facilitated by establishing boundaries for management in the vicinity of long stretches of sandy beaches and sandy benthic habitat offshore. Although sea otters forage over sandy areas devoid of rocky reef - kelp bed habitat, they have not been observed to establish rafting groups in such areas. In addition, long stretches of sandy beaches and sandy offshore habitat such as occur along Monterey Bay appear to provide partial barriers to range expansion.

Therefore, if resource uses adjacent to the present sea otter's range are to be protected from sea otter foraging, it is recommended that:

1. The sea otter's range be restricted in the coastal area between Moss Landing, Monterey County, and Morro Bay, San Luis Obispo County. These boundaries would allow for some sandy foraging habitat adjacent to the last rafting habitat at the extremes of the recommended area. Establishment of a southern boundary in the vicinity of Avila (near the next long stretch of sandy habitat along Pismo Beach) would adversely affect fisheries for abalones, crabs and sea urchins from Morro Bay to Avila and would present a high risk for potential damage to the important Pismo clam sportfishery along Pismo Beach.

2. A program be developed which will restrict sea otters to the recommended area.

3. Biological studies be designed and conducted concurrently to determine the progress and success of the management activities. These studies should provide that:

a. High priority be given to obtaining much needed additional sea otter population dynamics information. Such information must include additional data on birth and death rates, sex ratios, age composition, distribution and movements throughout the population.

   Much of this information can only be obtained by tagging animals throughout the range. It may be necessary to tag at least 10% or more of the population to obtain statistically significant data.

b. Further ecological studies be conducted throughout the range. Such studies should include effects of otters on the nearshore environment in terms of sea otter food resources, effects on kelp bed ecology and characteristics of established sea otter habitat. These studies should be designed to supply information necessary to establish range carrying capacity.

c. Scientific research on sea otters in captivity be continued. Continuing research on captive animals will provide further information on physiology, medical care and husbandry, food habits and behavior.

d. The program of sea otter carcass recovery, processing, and distribution of remains be continued.

e. When adequate information has been accumulated, management recommendations be updated to ensure continuance of a healthy population of sea otters.

We recommend against the second management alternative (that of an unrestricted sea otter population). Research has demonstrated that many valuable marine invertebrates cannot coexist with sea otters in numbers and sizes that can be utilized by man. Therefore, to follow this alternative would mean that human use of a variety of living marine resources would be sacrificed, in addition to those already lost, to sustain the expanding sea otter population.

If the alternative of not restricting the expansion of the sea otter population is selected, then the Department's continuing activities should be limited to sporadic surveillance and censusing of the population.

## REFERENCES

Allanson, A. 1955. Sea otters on San Miguel. Pac. Discovery, 8(3):24-25.

Barabash-Nikiforov, I. I., V. V. Reshetkin and N. K. Shidlovskaya. 1947. The sea otter (Kalan). Transl. from Russian by A. Birron and Z. S. Cole, 1962. Natl. Sci. Found. and U. S. Dept. Int., Washington, D. C. 277 p. (Israel Program for Sci. Transl.)

Bentley, W. W. 1959. Sea otter along the California coast. J. Mamm., 40(1):147.

Bissell, H., and F. Hubbard. 1968. Report on the sea otter, abalone and kelp resources in San Luis Obispo and Monterey Counties and proposals for reducing the conflict between the commercial abalone industry and the sea otter. Calif. Dept. Fish and Game, Sacramento. 72 p. (Senate Concurrent Resolution, 74, 1967 Legislative Sess.)

Bolin, R. L. 1938. Reappearance of the southern sea otter along the California coast. J. Mamm., 19(3):301-303.

Boolootian, R. A. 1961. The distribution of the California sea otter. Calif. Fish and Game, 47(3):287-292.

Bryant, H. C. 1915. Sea otter near Point Sur. Calif. Dept. Fish and Game, 1(3):134.

Burge, R. 1973. Cruise report 73-M-1: Abalone. Calif. Dept. Fish and Game, Mar. Resour. Reg. 7 p.

California, State of. 1937. Fish and Game Code 1937-1939. Calif. Dept. Fish and Game, Sacramento. 264 p.

—— 1955. Fish and Game Code 1955-57. Ibid. 356 p.

Carlisle, J. G., Jr. 1966a. Aerial censuses of California sea otter in 1964-1965. Calif. Fish and Game, 52(4):300-302.

—— 1966b. Flight report 66-7: Special Projects. Calif. Dept. Fish and Game, Mar. Resour. Oper. 1 p.

—— 1967a. Flight report 67-1: Sea otter. Ibid. 1 p.

—— 1967b. Flight report 67-7: Sea otter. Ibid. 1 p.

Cox, K. W. 1962. California abalones, family Haliotidae. Calif. Dept. Fish and Game, Fish Bull., (118):1-133.

Ebert, E. E. 1968a. A food habits study of the southern sea otter, *Enhydra lutris nereis*. Calif. Fish and Game, 54(1):33-42.

—— 1968b. California sea otter census and habitat survey. Underwater Nat., 5(3):20-23.

Estes, J. A., and N. S. Smith. 1973. Research on the sea otter, Amchitka Island, Alaska; final report. (Amchitka Bioenvironmental Program) Ariz. Coop. Wildl. Res. Unit, Univ. Ariz., Tucson. 68 p. (AEC contract AT(26-1)-520)

Farnsworth, G. 1917. Sea otter near Catalina Island. Calif. Fish and Game, 3(2):90.

Faro, J. B. 1969. A survey of subtidal sea otter habitat off Point Pinos, California. M.S. Thesis, Humboldt State College. 278 p.

Fisher, E. M. 1939. Habits of the southern sea otter. J. Mamm., 20(1): 21-36.

Hall, K. R. L., and G. B. Schaller. 1964. Tool-using behavior of the California sea otter. J. Mamm., 45(2):287-298.

Hennessy, S. L. 1972. The intestinal parasites and diet analysis of the southern sea otter. M.S. Thesis, Calif. St. Univ., Hayward. 44 p.

Howard, L. D. (In press). Muscular anatomy of the forelimb of the southern sea otter, *Enhydra lutris nereis*. Calif. Acad. Sci., Occas. Pap.

Kenyon, K. W. 1969. The sea otter in the Eastern Pacific Ocean. U. S. Bur. Sport Fish. and Wildl., No. Amer. Fauna, (68):1-352.

Lensink, C. J. 1962. The history and status of sea otters in Alaska. Ph.D. Thesis, Purdue Univ. 188 p. Univ. Microfilms, Ann Arbor, Mich.

Limbaugh, C. 1961. Observations on the California sea otter. J. Mamm., 42(2):271-273.

Mattison, J. A., Jr., and R. C. Hubbard. 1969. Autopsy findings on thirteen sea otters (*Enhydra lutris nereis*) with correlations with captive animal feeding and behavior. p. 99-101. *In* Sixth Ann. Conf. on Biol. Sonar and Diving Mammals, Stanford Res. Inst., Menlo Park, Calif. Proc.:1-113.

McLean, J. H. 1962. Sublittoral ecology of kelp beds of the open coast areas near Carmel, Caifornia. Biol. Bull., 122(1):95-114.

Miller, D. J., and D. Gotshall. 1965. Ocean sport fish catch and effort from Oregon to Point Arguello, California, July 1, 1957 - June 30, 1961. Calif. Dept. Fish and Game, Fish Bull., (130):1-135.

Minter, C. S., III. 1971. Sublittoral ecology of the kelp beds off Del Monte Beach, Monterey, California. M.S. Thesis, U.S. Naval Postgraduate School, Monterey. 180 p.

Odemar, M. W. 1969. Flight report 69-C-10: Sea otter. Calif. Dept. Fish and Game, Mar. Resour. Reg. 1 p.

Odemar, M. W., and K. C. Wilson. 1969a. Flight reports 69-C-1 and 69-C-2. Calif. Dept. Fish and Game, Mar. Resour. Reg. 2 p.

—— 1969b. Population studies of sea otters in California. Ibid., MRR Ref., (70-3):1-11.

—— 1969c. Results of sea otter capture, tagging, and transporting operations by the California Department of Fish and Game, p. 73-79. *In* Sixth Ann. Conf. on Biol. Sonar and Diving Mammals, Stanford Res. Inst., Menlo Park, Calif., Proc.:1-113.

Orr, R. T. 1959. Sharks as enemies of sea otters. J. Mamm. 40(4):614.

Orr, R. T., and T. C. Poulter. 1964. Northward movement of the California sea otter. Calif. Fish and Game, 50(2):122-124.

Oyer, P. H. 1917. Sea otter near Monterey. Calif. Fish and Game, 3(2):88.

Peterson, R. S., and M. W. Odemar. 1969. Population growth of the sea otter in California, p. 69-72. *In* Sixth Ann. Conf. on Biol. Sonar and Diving Mammals, Stanford Res. Inst., Menlo Park, Calif., Proc.:1-113.

Rausch, R. 1953. Studies on the helminth fauna of Alaska. 13. Disease in the sea otter, with special reference to helminth parasites. Ecology. 34(3):584-604.

Roest, A. I. (In press). Subspecies of the sea otter, *Enhydra lutris* L. Nat. Hist. Mus. Los Angeles Co., Contrib. Sci.

Schneider, K. B. 1972. Sea otter report. Alaska Dept. Fish and Game, Fed. Aid in Restoration, Proj. Prog. Rept., vol. 1, Proj. W-17-4, Jobs 8.9R and 8:10R. 26 p; 8 p.

Shaw, S. B. 1971. Chlorinated hydrocarbon pesticides in sea otters and harbor seals. Calif. Fish and Game, 57(4):290-294.

Stullken, D. E., and C. M. Kirkpatrick. 1955. Physiological investigations of captive mortality in the sea otter, *Enhydra lutris*. No. Amer. Wildl. Conf., Trans., (20):476-494.

Vandevere, J. E. 1969. Feeding behavior of the southern sea otter, p. 87-94. *In* Sixth Ann. Conf. on Biol. Sonar and Diving Mammals, Stanford Res. Inst., Menlo Park, Calif., Proc.:1-113.

Wild, P. W. 1971. Flight report 71-C-3: Sea otter. Calif. Dept. Fish and Game, Mar. Resour. Reg. 2 p.

Wilson, K. C. 1968a. Flight report 68-C-4: Sea otter-abalone. Calif. Fish and Game, Mar. Resour. Oper. 2 p.

—— 1968b. Flight report 68-C-5: Sea otter-abalone. Ibid. 1 p.

—— 1969a. Flight report 69-C-4: Sea otter. Ibid. 2 p.

—— 1969b. Flight report 69-C-5: Sea otter. Ibid. 2 p.

—— 1969c. Flight report 69-C-6: Sea otter. Ibid. 2 p.

—— 1969d. Flight report 69-C-7: Sea otter. Ibid. 2 p.

—— 1969e. Flight report 69-C-11: Sea otter. Ibid. 1 p.

—— 1969f. Flight report 69-C-13: Sea otter. Ibid. 1 p.

—— 1970. Flight report 70-C-3: Sea otter. Ibid. 4 p.

—— 1971a. Flight report 71-C-1: Sea otter. Ibid. 2 p.

—— 1971b. Flight report 71-C-4: Sea otter. Ibid. 3 p.

—— 1971c. Flight report 71-C-5: Sea otter. Ibid. 2 p.

—— 1972a. Flight report 72-C-1: Sea otter. Ibid. 3 p.

—— 1972b. Flight report 72-C-5: Sea otter. Ibid. 2 p.

Wilson, K. C., and M. Odemar. 1968. Flight report 68-C-9: Sea otter-abalone. Calif. Fish and Game, Mar. Resour. Oper. 2 p.

—— 1969. Flight report 69-C-9: Sea otter. Calif. Fish and Game, Mar. Resour. Reg. 2 p.

—— 1970. Flight report 70-C-1: Sea otter. Ibid. 2 p.

# APPENDIX I

## DATA DOCUMENTING THE ABALONE FISHERY - SEA OTTER RESOURCE CONFLICT

Commercial abalone beds in the area from Cape San Martin to Cayucos, a distance of 74 km (46 miles), harvested since 1929 (Cox, 1962), have been gradually abandoned from north to south. By the end of the 1950's the Cape San Martin area was abandoned by commercial divers (Glen Bickford, pers. commun.). The Beckett's Reef area in the vicinity of Point Piedras Blancas became unproductive in the early 1960's and was abandoned about 1964 (Bissell and Hubbard, 1968). This area had yielded a good crop of abalones annually for over 30 years. In 1968, Department of Fish and Game biologists predicted the collapse of the fishery in the Cambria-Point Estero area and this last area was abandoned by commercial divers in 1971 (Richard Burge, pers. commun.). The Cambria-Point Estero area had withstood heavy fishing pressure for nearly 40 years.

The abandonment of the fishing grounds most remote from home port first was highly unusual since their remoteness made 1 day trips from Morro Bay unfeasible and the closest anchorage was at San Simeon which was considered safe only from about May to mid-October (Glen Bickford, pers. commun.). Thus these beds received less prolonged pressure each season and should have been expected to hold up the longest if overfishing were occurring.

Red abalone landings at San Simeon and Morro Bay reflect the declining harvest to the north (Table 1). The Morro Bay figures include landings from the Point Buchon-Avila area, as well as a small percentage from the Channel Islands and other areas and thus obscure a sharper decline which actually occurred in the beds north of Morro Bay. Red abalone landings at Santa Barbara have remained relatively stable for nearly 20 years (Table 1).

Departmental Abalone Project surveys of the red abalone population in the Cambria-Point Estero area indicate that prior to 1971 the abalone stocks in this last very productive area north of Morro Bay had sufficient numbers of legal and sublegal red abalones to provide for a continuing sustained yield (Figure 1). However, sampling in 1971 and 1973 indicated that a significant reduction in the numbers of all sizes of abalones had occurred. Commercial abalone fishing has been virtually non-existent in this area since early 1971. The dramatic depletion of a wide range of smaller red abalones could not have been caused by sport or commercial abalone harvesting in the area, since the minimum size limits, 197 mm (7-3/4 inches) for commercial and 178 mm (7 inches) for sport harvesting, provide a wide margin of safety for red abalone spawning stocks.

In each case, an influx of sea otters has occurred a few years prior to the abandonment of abalone beds by commercial divers in the Cape San Martin to Cayucos area. By 1950 sea otters were sighted off Cape San Martin and by 1953 they were reported as far south as Salmon Creek

APPENDIX I

TABLE 1. Red Abalone Landings in Pounds* at San Simeon, Morro Bay, Avila, Santa Barbara and Statewide from 1953 through 1972.

| Year | San Simeon | Morro Bay | Avila | Santa Barbara | Statewide |
|---|---|---|---|---|---|
| 1953 | 126,375 | 132,321 | 148,382 | 248,934 | 1,412,949 |
| 1954 | 436,750 | 166,270 | 89,897 | 494,526 | 1,394,485 |
| 1955 | 475,900 | 322,291 | 93,334 | 847,387 | 1,996,511 |
| 1956 | 806,504 | 689,575 | 68,942 | 686,752 | 2,424,393 |
| 1957 | 527,168 | 562,282 | 154,047 | 1,035,806 | 2,569,025 |
| 1958 | 183,465 | 232,515 | 79,987 | 816,688 | 1,677,404 |
| 1959 | 40,328 | 579,804 | 58,460 | 1,045,705 | 2,180,658 |
| 1960 | 131,860 | 1,008,051 | 57,152 | 856,578 | 2,693,857 |
| 1961 | 178,167 | 1,597,786 | 40,363 | 708,250 | 2,873,628 |
| 1962 | 11,596 | 1,212,448 | 35,515 | 888,383 | 2,462,200 |
| 1963 | | 1,083,728 | 97,050 | 998,041 | 2,807,921 |
| 1964 | 2,200 | 1,102,677 | 12,895 | 1,106,131 | 2,369,574 |
| 1965 | | 1,278,656 | 57,077 | 916,431 | 2,490,875 |
| 1966 | | 1,442,653 | 116,850 | 935,295 | 2,656,408 |
| 1967 | | 1,395,757 | 224,616 | 887,907 | 2,691,610 |
| 1968 | | 655,653 | 269,905 | 717,367 | 1,776,054 |
| 1969 | | 427,300 | 184,132 | 776,396 | 1,564,205 |
| 1970 | | 163,306 | 121,105 | 722,911 | 1,194,788 |
| 1971 | | 188,537 | 112,269 | 833,171 | 1,283,567 |
| 1972 | | 219,687 | 78,793 | 640,543 | 1,104,462 |

* 1 kg = 2.2 lb

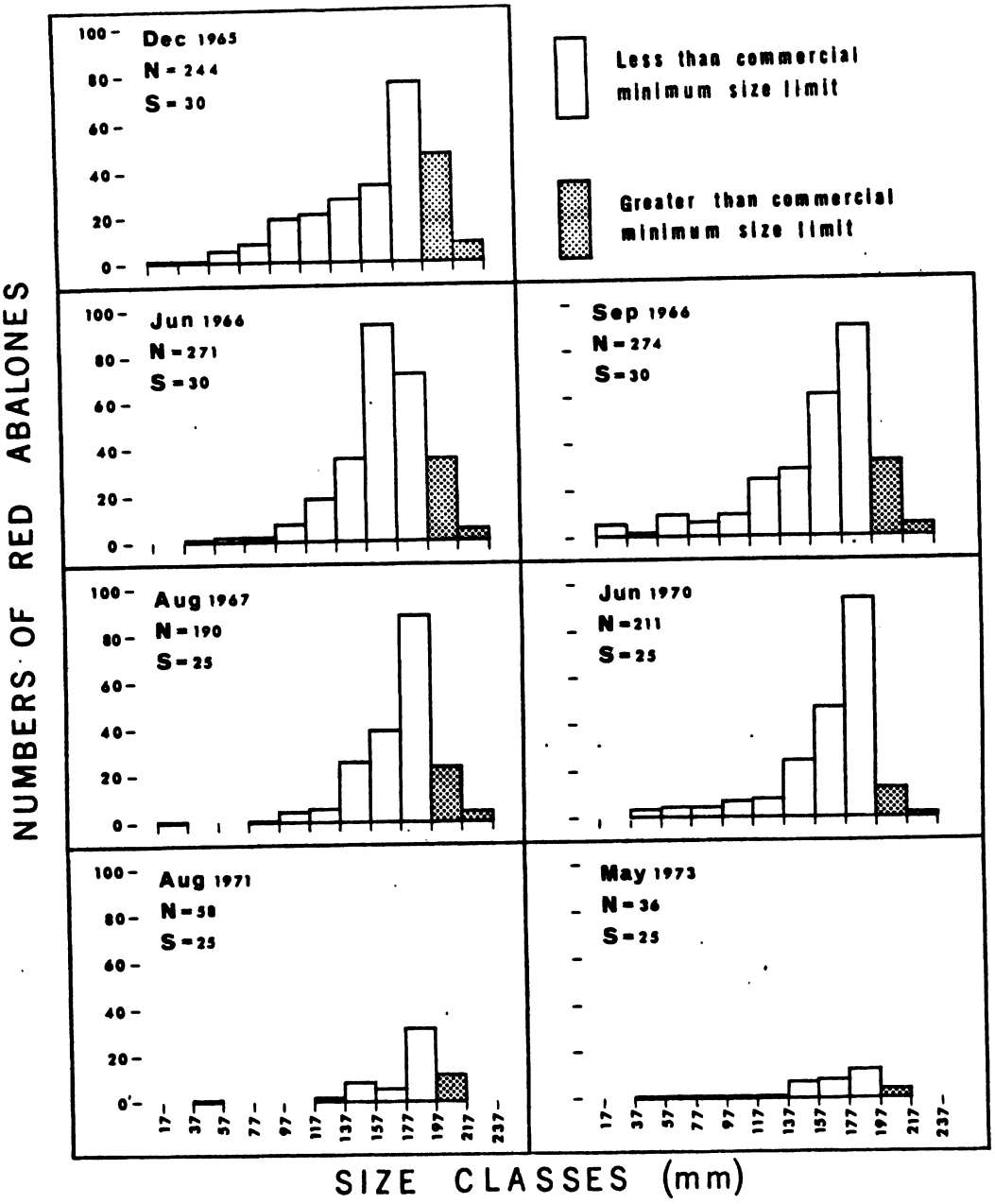


FIGURE 1. Numbers and sizes of red abalones sampled between Cambria and Point Estero from 1965 through 1973. N = number of abalones. From 1965 through 1967, N includes only abalones retrieved and measured. Since 1970, N also includes some abalones seen and not retrieved for which size was estimated. S = number of 4 x 30 m (13 x 100 ft) transects. Data provided by Dick Burge (CDFG Abalone Project), who plans to analyze and publish them later.

(Peterson and Odemar, 1969). In 1956, 93 sea otters were reported from Salmon Creek to Point Piedras Blancas (Boolootian, 1961). By 1969, sea otters were regularly seen between Cambria and Point Estero and in 1972 near Cayucos. In January 1973 the sea otter's range was extended to Point Buchon. The Avila and remaining Morro Bay landings can be expected to decline as sea otter foraging begins to affect the harvest south of Morro Bay.

Records of sea otter range expansion along with sport fishing data reveal that trends paralleling those observed in the commercial abalone fishery north of Morro Bay also occurred in the sport fishery for abalones from Monterey to Point Estero.

Miller and Gotshall (1965) report that in 1960 sport divers took nearly 10 thousand abalones along the 253 km (157 miles) of coastline from Seaside to Pismo Beach. However, analysis of the original data reveals that very few of these abalones came from the large area between Point Pinos and Point Piedras Blancas (Figure 2). The sea otter population at that time ranged from about Point Pinos to the vicinity of San Simeon.

A survey in 1972 revealed a dramatic increase in the sport take of abalones outside the sea otter's range, while the sport take of abalones had virtually ceased where the sea otter's range had expanded to the north and south (Figure 2). By early 1972 the sea otter population ranged between Seaside and Cayucos. By the end of 1972 the sport abalone take at Cayucos also had virtually ceased (Daniel Miller, pers. commun.).

Along the short stretch of coast between Point Pinos and Monterey, where approximately 5 thousand red abalones were taken by skindivers in 1960 (Miller and Gotshall, 1965), an estimated 25 were taken in 1972. Miller (pers. commun.) also reports that "In 1960 the area from Point Piedras Blancas to Cambria (near Point Estero) yielded the highest sport abalone-per-hour values in all central and northern California. However, not a single abalone was taken by the 52 divers interviewed between Point Piedras Blancas and Cambria in 1972."

In addition, Miller reports that the sport take of other invertebrates, such as red and rock crabs and sea urchins, is significantly less within than without the sea otter's range.

The impact of the sea otter range expansion was difficult to assess initially, due to a warm water period from 1957 to 1959 reducing kelp and abalone growth in some areas (Cox, 1962), the concurrent lowering of the size limit of commercial abalones from 203 mm to 197 mm (8 inches to 7-3/4 inches) in 1959, the earlier lack of long term abalone sportfishing data, and sparse information on food habits and behavior of sea otters in California.

APPENDIX I

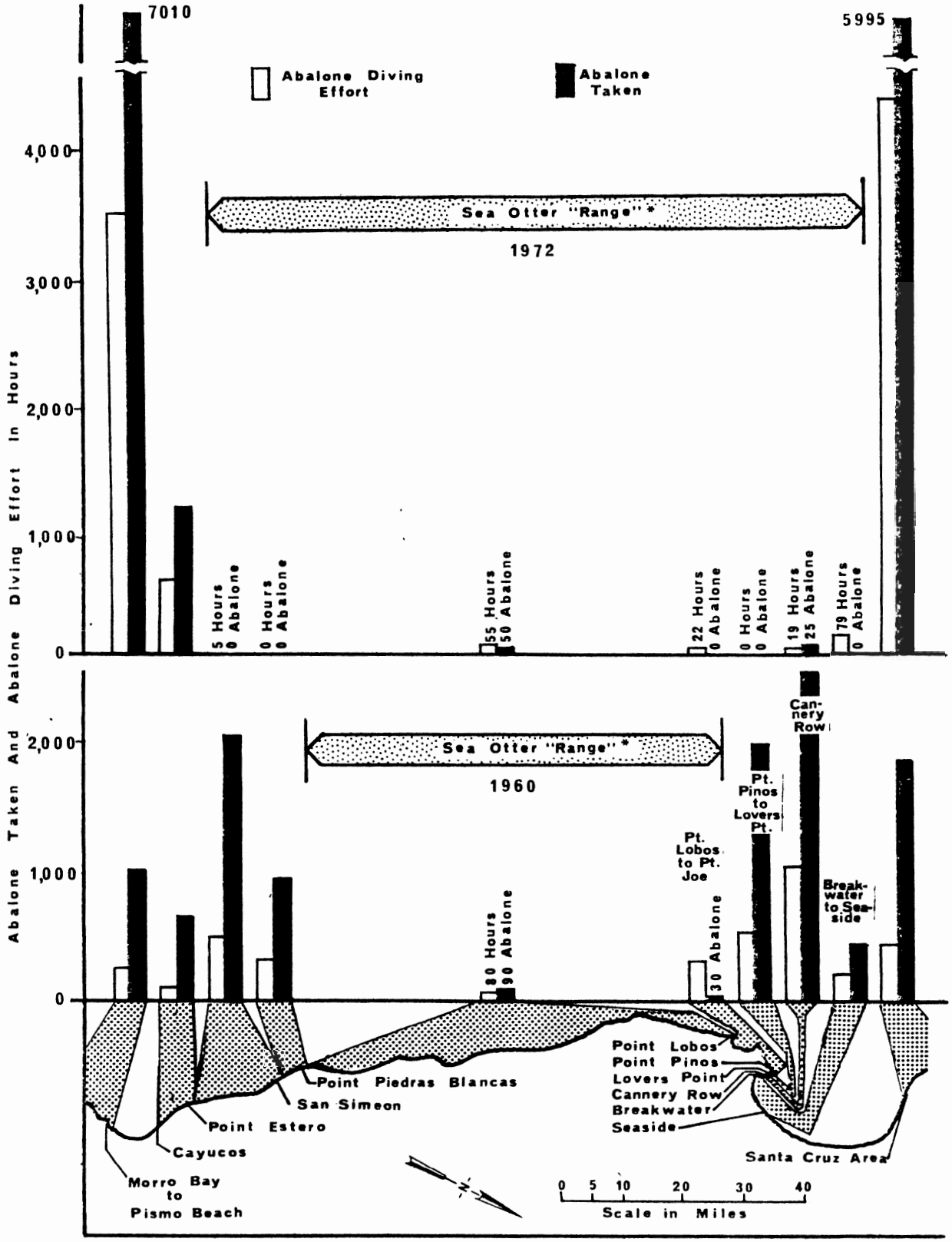


FIGURE 2. Number of hours spent diving for abalone and number of abalone landed by skindivers in 1960 and 1972 from Pismo Beach to Santa Cruz. Figure provided by Daniel Miller, CDFG Central California Sportfish Project.

* The sea otter's "range" is the area in which numbers of sea otters have been foraging for several years.

APPENDIX I

A considerable amount of additional information has been accumulated which provides firm evidence of the profound effect sea otters exert on the nearshore environment. This information also indicates the devastating effect that sea otters can have on sport and commercial harvests of certain invertebrates foraged upon by sea otters.

An extensive Departmental diving survey conducted in 1967 from Monterey to Point Estero revealed that throughout the sea otter's range preferred sea otter forage items including sea urchins, abalones, and rock crabs were severely reduced in numbers and restricted to protected habitat. However, from Cambria to Point Estero, where otters were not in significant numbers and commercial divers were still operating, these same organisms were more abundant and more readily available in open habitat (Ebert, 1968b) (Table 2, Figure 3). Recent surveys reveal that the depletion of these organisms now extends into the Cambria-Point Estero area (Burge, 1973). The significant observation is that, where otters forage intensively not only are abalones reduced in numbers and limited to protected habitat, but that other preferred sea otter forage items such as sea urchins and crabs, even in areas where they are not subjected to sport or commercial harvest, are similarly affected.

The impact of sea otters on the abalone resource can further be demonstrated from the knowledge of sea otter food requirements and feeding behavior, the percent of abalones observed in the diet in newly colonized areas in the vicinity of abalone fisheries; and the number and average weight of sea otters present in such areas.

Sea otters in captivity have been found to require 20 to 35% of their body weight in food each day (Stullken and Kirkpatrick, 1955; Kenyon, 1969). Two adult sea otters in captivity in California were found to require 25% of their body weight in food each day (Richard Hubbard, DVM pers. commun.). A sea otter in the wild may require more food because of higher energy expenditure. Food habits studies of sea otters in newly colonized areas near commercial ablone beds reveal that abalones constituted 63% (Ebert, 1968a) to 72% of the items observed in their diet.

The range expansion and influx of sea otters into the Cambria-Point Estero area have been well documented. In 1967, 15 to 30 sea otters were observed in this area (Bissell and Hubbard, 1968). In 1968, a maximum of 62 sea otters was observed there (Wilson, 1968b). During 1969, 1970 and 1971 as many as 129, 165 and 187 sea otters, respectively, were observed in the Cambria-Point Estero area (Wilson, 1969a; Wilson and Odemar, 1970; Wild, 1971).

Twenty-one sea otters captured and weighed at Cambria in 1969 ranged from 16 to 34 kg (36 to 76 lb) with an average weight of 26 kg (57 lb).

TABLE 2. Abundance of Species Determined During a Sea Otter Census and Habitat Survey of Stations in Six Regions of the Central California Coast, Pacific Grove to Point Estero, October 17, 18, and 19, 1967.*

| Region (See Fig. 3) | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| Number of Stations | 15 | 10 | 16 | 16 | 16 | 18 |
| SPECIES | | | | | | |
| Giant kelp *Macrocystis angustifolia* | S to D** | S to D | S to D | M to D | M to D | S to D |
| Bull kelp *Nereocystis leutkeana* | S to D | S to M | S to M | S to M | S to D | S to D |
| Tree kelp *Pterygophora californica* | S to D | M to D | S to D | M to D | S to D | S to D |
| Red abalone *Haliotis rufescens* | (19) | (38) | (20) | (53) | (64) | (126)45 |
| Flat abalone *H. walallensis* | (5)1 | (1) | (19) | (9)1 | (14) | (4) |
| Pinto abalone *H. kamtschatkana* | (10)2 | (5)5 | (1)1 | -- | 1 | (8)4 |
| Rock crab *Cancer antennarius* | (5)3 | (1)2 | (2) | (3)4 | 2 | (13)2 |
| Spider crab *Loxorhynchus grandis* | 5 | (4)2 | 7 | 13 | 2 | (8)41 |

TABLE 2 (continued)

| Region (See Fig. 3) | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| Number of Stations | 15 | 10 | 16 | 16 | 16 | 18 |
| SPECIES | | | | | | |
| Kelp crab *Pugettia producta* | 1 | -- | 1 | 1 | 2 | 1 |
| Red sea urchin *Strongylocentrotus franciscanus* | (4) | -- | (2) | 6 | (3) | (45)490 |
| Purple sea urchin *S. purpuratus* | (7) | (1)11 | (2) | -- | (3) | (4)100 |
| Rock scallop *Hinnites multirugosus* | 7 | (11) | 8 | (11)18 | (26)2 | (52)28 |
| Gumboot chiton *Cryptochiton stelleri* | (4)55 | (8)47 | (2)96 | (5)100 | (1)53 | 67 |
| Southern sea otter *Ennydra lutris nereis* | 70 | 59 | 32 | 15 | 16 | 20 |

* After Ebert, 1968b.

** Abundance symbols
S - Sparse - scattered throughout the area but nowhere numerous.
M - Moderate - present throughout the area and only occasionally numerous.
D - Dense - numerous and evenly distributed throughout the area.
() - Parentheses denotes organisms occurring in protective niches. Total for a particular organism is the sum of both values.

APPENDIX I

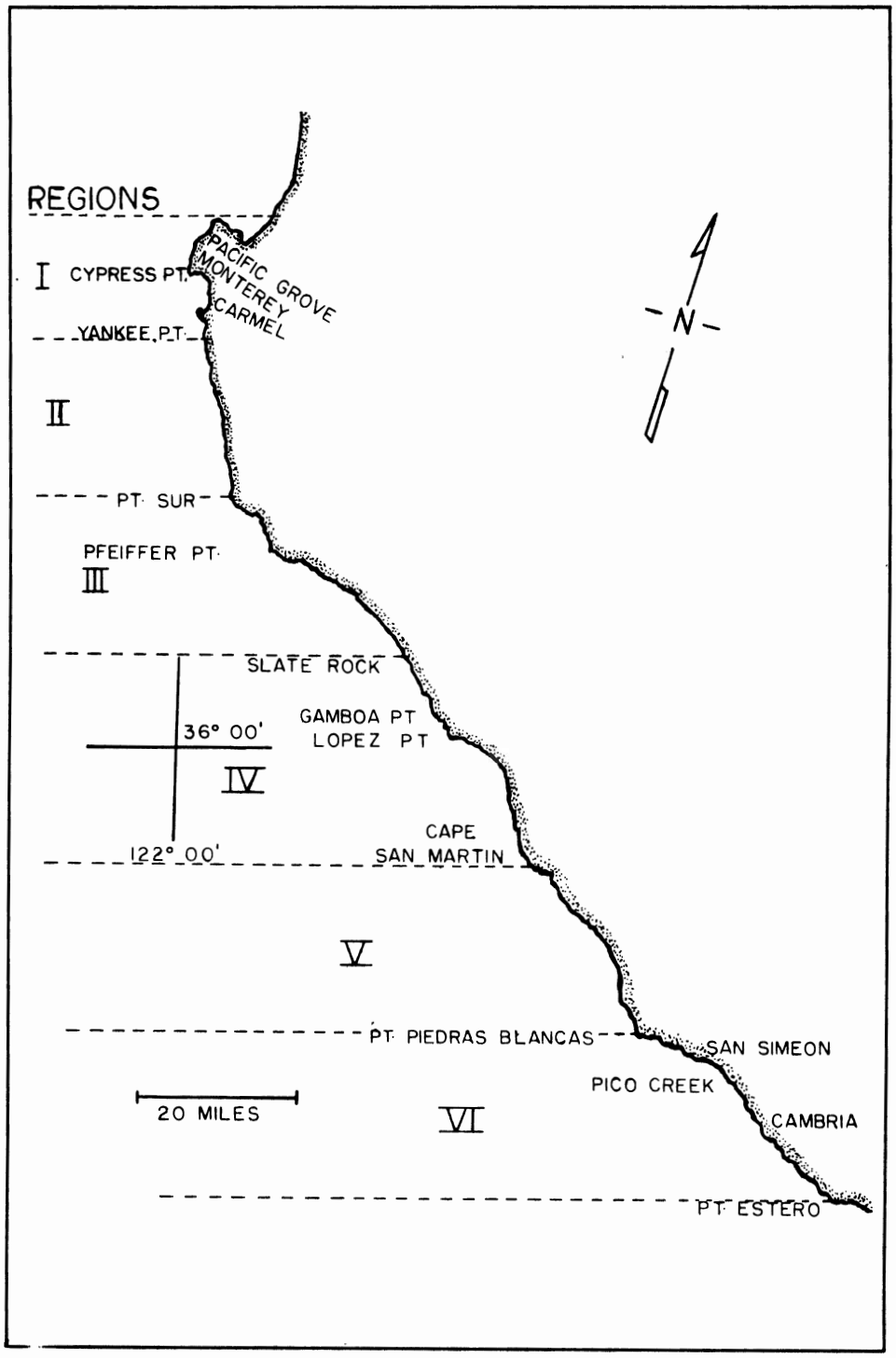


Figure 3. Central California Coast. Diving stations were established at approximately 1-mile intervals, in six regions, between Pacific Grove and Pt. Estero (from Ebert, 1968b).

APPENDIX I

The preceding information makes it possible to calculate the effect that as few as 100 sea otters can have on abalone populations within a relatively short time period. In newly colonized areas where abalones are abundant, 100 sea otters could consume from 230 thousand to 460 thousand kg (0.5 to 1.0 million lb) of abalone (whole weight) in 1 year. The calculations from which these figures are derived are as follows:

The percentages of abalone observed in the sea otter's diet in newly colonized areas are:

| | | |
|---|---|---|
| Pico Creek, 1966 | 63% | (Ebert, 1968a) |
| Point Estero, 1971 | 72% | (Food Habits Studies, this report) |

These percentages are by number of organisms eaten, not by weight. Since the biomass of abalones is in general much greater than for other organisms in the diet, the percent by weight would be much higher. This is particularly true in newly colonized areas where there is an abundance of large abalones.

Ebert (1968a) reports:

| | | |
|---|---|---|
| One 178 mm (7 inch) red abalone equals: | 63.0 | sea mussels |
| or: | 10.7 | rock scallops |
| or: | 3.0 | red sea urchins |
| or: | 31.6 | purple sea urchins |
| or: | 2.2 | gaper clams |

Ebert (pers. commun.) also reports:

Red abalone biomass: (all soft parts)

| Shell Diameter | | Weight | |
|---|---|---|---|
| mm | (inches) | kg | (lb) |
| 102 | (4) | 0.1 | (0.3) |
| 127 | (5) | 0.2 | (0.5) |
| 153 | (6) | 0.5 | (1.1) |
| 178 | (7) | 0.7 | (1.5) |
| 197 | (7-3/4) | 1.0 | (2.1) |
| 203 | (8) | 1.0 | (2.2) |
| 229 | (9) | 1.5 | (3.4) |

In the following calculations we have assumed the percent of abalones in the diet by number to be equal to the percent by weight, recognizing that the results are probably conservative.

APPENDIX I

If 63% of the diet is abalone, a 26 kg (57 lb) sea otter may consume from 3.3 to 5.6 kg (7.2 to 12.3 lb) of abalone per day. If 72% of the diet is abalone, the same size otter may consume from 4.6 to 6.6 kg (10.0 to 14.4 lb) per day.

Since commercial abalone landings are based on whole weight (shell and soft parts) which is figured at 22.7 kg (50 lb) per dozen, a conversion factor is needed to compare sea otter consumption by biomass[1/] to commercial landings.

Using a 203 mm (8 inch) abalone with 1 kg (2.2 lb) of biomass as a basis, a dozen 203 mm (8 inch) abalones would weigh 12 kg (26.4 lb). At 22.7 kg (50 lb) per dozen whole weight, a conversion factor for converting biomass to whole weight is obtained as follows:

$$\frac{\text{22.7 kg (whole wt)}}{\text{12.0 kg (biomass)}} = 1.9 = \text{conversion factor}$$

Smaller abalones would give higher conversion factors while larger ones would give smaller conversion factors. A 203 mm (8 inch) red abalone is assumed to be about average for purposes of computing a conversion factor because the minimum legal commercial size for red abalone is 197 mm (7-3/4 inches). Therefore, using possible minimum, 3.3 kg (7.2 lb), and maximum, 6.6 kg (14.4 lb), daily consumption figures,

1.9 x 3.3 kg = 6.3 kg (1.9 x 7.2 lb = 13.7 lb) of abalone (whole weight) per day per otter;

and 1.9 x 6.6 kg = 12.6 kg (1.9 x 14.4 lb = 27.4 lb) of abalone (whole weight) per day per otter.

Then, the probable whole weight consumption of abalone by 100 otters in a year is determined as follows:

6.3 kg x 365 x 100 = 229,995 kg (13.7 lb x 365 x 100 = 500,050 lb)

12.6 kg x 365 x 100 = 459,900 kg (27.4 lb x 365 x 100 = 1,000,100 lb)

Therefore, using all the available data, in newly colonized areas where abalones are abundant, 100 sea otters could consume from 230 thousand to 460 thousand kg (0.5 to 1.0 million lb) of abalone (whole weight) in a year's time.

---

[1/] For purposes of these calculations biomass is considered to be the difference between total wet weight and shell weight.

APPENDIX I

A 203 mm (8 inch) abalone contains 2 times the biomass of a 153 mm (6 inch) abalone and more than 7 times the biomass of a 102 mm (4 inch) abalone. Thus, sea otters would require twice the number of 153 mm (6 inch) abalones and more than 7 times the number of 102 mm (4 inch) abalones to equal the food recovery from a 203 mm (8 inch) abalone and correspondingly more for smaller sizes. Because sea otters feed on abalones of all sizes the impact on spawning stock and recruitment is considerable.

Since sea otters utilize abalones in a wide range of sizes, they reduce the spawning stock necessary to perpetuate a large sustained yield fishery. The large sustained yield abalone fishery which existed in the area north of Point Estero for many years (Table 1) was based on scientific management techniques which protected spawning stock and recruitment. The evidence indicates that the loss of sport and commercial abalone fisheries which once existed in the sea otter's present range has resulted from the foraging activities of an expanding sea otter population.

## APPENDIX II

### SEA OTTER DENSITY CALCULATION DATA

Table 1. Sea Otter Density Calculation Data for Entire Established Range.

| Date | Aerial Count* | Adjustment Factor† | Population Estimate | Miles$^2$ of Habitat‡ | Density (Otters/Mile$^2$) | Average Annual Density |
|---|---|---|---|---|---|---|
| Nov 8, 1968 | 663 (1) | 65% | 1020 | 116.9 | 8.7 | 1968 |
| Dec 20, 1968 | 377 | 30% | 1257 | 116.9 | 10.8 | 9.8 |
| Jan 31, 1969 | 983 | 75% | 1311 | 116.9 | 11.2 | 1969 |
| Feb 10, 1969 | 770 | 60% | 1283 | 116.9 | 11.0 | |
| Mar 10, 1969 | 931 | 70% | 1330 | 116.9 | 11.4 | |
| Jun 2, 1969 | 1014 | 75% | 1352 | 116.9 | 11.6 | 11.2 |
| Aug 1, 1969 | 529 | 45% | 1176 | 116.9 | 10.1 | |
| Oct 6, 1969 | 483 | 35% | 1380 | 116.9 | 11.8 | |
| Dec 1, 1969 | 649 | 50% | 1298 | 116.9 | 11.1 | |
| May 6, 1970 | 313 (1) | 75% | 417 | 116.9 | 13.0 | 1970 |
| May 7, 1970 | 717 (9) | 65% | 1103 | | | |
| | 1030(10) | | 1520 | | | 11.8 |
| Sep 16-17, 1970 | 611 (1) | 50% | 1222 | 116.9 | 10.5 | |
| Feb 12-13, 1971 | 715 (3) | 50% | 1430 | 116.9 | 12.2 | 1971 |
| Apr 15-16, 1971 | 899 (3) | 60% | 1498 | 116.9 | 12.8 | |
| Jun 30, 1971 - Jul 1, 1971 | 956 (3) | 60% | 1593 | 116.9 | 13.6 | 13.1 |
| Oct 5-6, 1971 | 707 (8) | 45% | 1571 | 116.9 | 13.4 | |
| Jan 4-5, 1972 | 1059 (1) | 65% | 1629 | 121.9§ | 13.4 | 1972 |
| Apr 19, 1972 | 377 | 35% | 1077 | 121.9§ | 13.8 | 13.6 |
| Apr 20, 1972 | 393 | 65% | 605 | | | |
| | 770 | | 1682 | | | |

* Numbers in parentheses denote animals observed outside the established range at the time. These numbers were excluded from density calculations and, therefore, population estimates in some cases differ slightly from total population estimates in section on Population Dynamics, Table 1.

† See section on Population Dynamics, Table 1.

‡ Area between the shoreline and the 37 m (20 fathom) contour. 1 mile$^2$ = 2.590 km$^2$.

§ Established range in January 1972 was Seaside to Point Estero (116.9 miles$^2$), but in April 1972 it was Seaside to Cayucos (126.9 miles$^2$). These were averaged to get habitat for 1972 (121.9 miles$^2$).

APPENDIX II

TABLE 2. Sea Otter Density Calculation Data for Portion of Established Range Between North and South Sea Otter Game Refuge Boundaries.

| Date | Aerial Count | Adjustment Factor* | Population Estimate | Miles$^2$ of Habitat† | Density (Otters/Mile$^2$) | Average Annual Density |
|---|---|---|---|---|---|---|
| Nov 8, 1968 | 438 | 65% | 674 | 92.2 | 7.3 | 1968 |
| Dec 20, 1968 | 259 | 30% | 863 | 92.2 | 9.4 | 8.4 |
| Jan 31, 1969 | 694 | 75% | 925 | 92.2 | 10.0 | 1969 |
| Feb 10, 1969 | 467 | 60% | 778 | 92.2 | 8.4 | |
| Mar 10, 1969 | 569 | 70% | 813 | 92.2 | 8.8 | |
| Jun 2, 1969 | 741 | 75% | 988 | 92.2 | 10.7 | |
| Aug 1, 1969 | 373 | 45% | 829 | 92.2 | 9.0 | 9.5 |
| Oct 6, 1969 | 313 | 35% | 894 | 92.2 | 9.7 | |
| Dec 1, 1969 | 457 | 50% | 914 | 92.2 | 9.9 | |
| May 6, 1970 | 99 | 75% | 132 | 92.2 | 10.8 | 1970 |
| May 7, 1970 | 561 | 65% | 863 | | | |
| | 660 | | 995 | | | 10.0 |
| Sep 16-17, 1970 | 429 | 50% | 858 | 92.2 | 9.3 | |
| Feb 12-13, 1971 | 488 | 50% | 976 | 92.2 | 10.6 | 1971 |
| Apr 15-16, 1971 | 465 | 60% | 775 | 92.2 | 8.4 | |
| Jun 30, 1971 - Jul 1, 1971 | 525 | 60% | 875 | 92.2 | 9.5 | 9.7 |
| Oct 5-6, 1971 | 423 | 45% | 940 | 92.2 | 10.2 | |
| Jan 4-5, 1972 | 843 | 65% | 1297 | 92.2 | 14.1 | 1972 |
| Apr 19, 1972 | 153 | 65% | 235 | 92.2 | 11.4 | 12.8 |
| Apr 20, 1972 | 286 | 35% | 817 | | | |
| | 439 | | 1052 | | | |

* See section on Population Dynamics, Table 1.

† Area between the shoreline and 37 m (20 fathom) contour. 1 mile$^2$ = 2.590 km$^2$.

APPENDIX II

Table 3. Sea Otter Density Calculations Data for Portion of Established Range North of Sea Otter Game Refuge.

| Date | Aerial Count* | Adjustment Factor† | Population Estimate | Miles$^2$ of Habitat‡ | Density (Otters/Mile$^2$) | Average Annual Density |
|---|---|---|---|---|---|---|
| Nov 8, 1968 | 163 | 65% | 251 | 13.4 | 18.7 | 1968 |
| Dec 20, 1968 | 84 | 30% | 280 | 13.4 | 20.9 | 19.8 |
| Jan 31, 1969 | 172 | 75% | 229 | 13.4 | 17.1 | 1969 |
| Feb 10, 1969 | 203 | 60% | 338 | 13.4 | 25.2 | |
| Mar 10, 1969 | 233 | 70% | 333 | 13.4 | 24.9 | |
| Jun 2, 1969 | 233 | 75% | 311 | 13.4 | 23.2 | 22.3 |
| Aug 1, 1969 | 97 | 45% | 216 | 13.4 | 16.1 | |
| Oct 6, 1969 | 127 | 35% | 363 | 13.4 | 27.1 | |
| Dec 1, 1969 | 151 | 50% | 302 | 13.4 | 22.5 | |
| May 6, 1970 | 214 (1) | 75% | 285 | 13.4 | 21.3 | 1970 |
| Sep 16, 1970 | 137 (1) | 50% | 274 | 13.4 | 20.4 | 20.8 |
| Feb 12, 1971 | 167 (3) | 50% | 334 | 13.4 | 24.9 | 1971 |
| Apr 15, 1971 | 272 (3) | 60% | 453 | 13.4 | 33.8 | |
| Jun 30, 1971 | 247 | 60% | 412 | 13.4 | 30.7 | 30.8 |
| Jul Oct 6, 1971 | 205 (1) | 45% | 456 | 13.4 | 34.0 | |
| Jan 5, 1972 | 141 (1) | 65% | 217 | 13.4 | 16.2 | 1972 |
| Apr 20, 1972 | 240 | 65% | 369 | 13.4 | 27.5 | 21.8 |

* Numbers in parentheses denote animals observed outside the established range at the time and were excluded from density calculations.

† See section on Population Dynamics, Table 1.

‡ Area between the shoreline and 37 m (20 fathom) contour. 1 mile$^2$ = 2.590 km$^2$.

APPENDIX II

TABLE 4. Sea Otter Density Calculation Data for Portion of Established Range South of Sea Otter Game Refuge.

| Date | Aerial Count* | Adjustment Factor† | Population Estimate | Miles$^2$ of Habitat‡ | Density (Otters/Mile$^2$) | Average Annual Density |
|---|---|---|---|---|---|---|
| Nov 8, 1968 | 62 (1) | 65% | 95 | 11.3 | 8.4 | 1968 |
| Dec 20, 1968 | 34 | 30% | 113 | 11.3 | 10.0 | 9.2 |
| Jan 31, 1969 | 117 | 75% | 156 | 11.3 | 13.8 | 1969 |
| Feb 10, 1969 | 100 | 60% | 167 | 11.3 | 14.8 | |
| Mar 10, 1969 | 129 | 70% | 184 | 11.3 | 16.3 | |
| Jun 2, 1969 | 40 | 75% | 53 | 11.3 | 4.7 | 11.3 |
| Aug 1, 1969 | 59 | 45% | 131 | 11.3 | 11.6 | |
| Oct 6, 1969 | 43 | 35% | 123 | 11.3 | 10.9 | |
| Dec 1, 1969 | 41 | 50% | 82 | 11.3 | 7.3 | |
| May 7, 1970 | 156 (9) | 65% | 240 | 11.3 | 21.2 | 1970 |
| Sep 17, 1970 | 45 | 50% | 90 | 11.3 | 8.0 | 14.6 |
| Feb 13, 1971 | 60 | 50% | 120 | 11.3 | 10.6 | 1971 |
| Apr 16, 1971 | 162 | 60% | 270 | 11.3 | 23.9 | 19.3 |
| Jul 1, 1971 | 184 (3) | 60% | 307 | 11.3 | 27.2 | |
| Oct 5, 1971 | 79 (7) | 45% | 176 | 11.3 | 15.6 | |
| Jan 4, 1972 | 75 | 65% | 115 | 16.3§ | 7.1 | 1972 |
| Apr 19, 1972 | 91 | 35% | 260 | 16.3§ | 16.0 | 11.6 |

* Numbers in parentheses denote animals observed outside the established range at the time and were excluded from density calculations.

† See section on Population Dynamics, Table 1.

‡ Area between the shoreline and 37 m (20 fathom) contour. 1 mile$^2$ = 2.590 km$^2$.

§ The portion of the established range south of the Sea Otter Game Refuge was 11.3 miles$^2$ in January 1972, but 21.3 miles$^2$ in April 1972. These were averaged to 16.3 miles$^2$ for density calculation.