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POPULATION KINETICS AND RELATED ECOLOGY OF THE NORTHERN SEA LION,
EUMETOPIAS JUBATUS, AND THE CALIFORNIA SEA LION,
ZALOPHUS CALIFORNIANUS, ALONG THE OREGON COAST

by

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A DISSERTATION

Presented to the Department of Biology and the Graduate School
of the University of Oregon
in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

March 1973

*My thanks to OIMB
and staff
Bruce*

An Abstract of the Dissertation of

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in the Department of Biology to be taken March 1973

Title: Population Kinetics and related Ecology of the Northern Sea
Lion, Eumetopias jubatus, and the California Sea Lion, Zalophus
californianus, along the Oregon Coast

Approved:

Dr. Paul Rudy

Northern sea lions, Eumetopias jubatus, and male California sea lions, Zalophus californianus, move seasonally along the Oregon coast. Northern sea lions breed at several locations in Oregon and males are present in the state from May through October. Male California sea lions move northward en masse into Oregon during August, after their breeding season, and cohabit areas being used by the Northern sea lions. The migration is well ordered and a distinct population "peak" can be observed moving northward at a uniform rate of speed. The "peak," while discernible, diminishes considerably in the north as individuals drop out of the migration to over-winter at suitable hauling areas in southern Oregon. Male Northern sea lions move out of such areas after California sea lions arrive. As the number of California sea lions increase at any given location, there are changes in interspecific behavior. An analysis of factors influencing sea lion populations daily and seasonally is made and an interpretation of these fluctuations is presented.

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March 6, 1973

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PREFACE

The main thrust of this study was to determine the population fluctuations of sea lions along the Oregon coast, and compare these with data collected by other observers to describe the annual migrations first hypothesized by Fry (1939). During the course of this work, periferal areas of interest have led, in many cases, to new information regarding the biology of these species. Information on population dynamics and disease have been included in this thesis in the form of appendices because of their close relationship with phenomena described in the thesis. Further information on aging, disease, heavy metals, chlorinated hydrocarbons, polychlorinated biphenyls, diving physiology, feeding, and natural history has not been included, but has been submitted for publication to various special interest journals, some of which are already in press (see Vita).

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CHAPTER I

INTRODUCTION

Previous Studies

Numerous studies have been made on the comparative anatomy, physiology, and social behavior of many pinnipeds throughout the world (Scheffer, 1958; King, 1964; Harrison and King, 1965). Behavioral research in the past has emphasized studies of territoriality and mating associated with the breeding season (Peterson, 1965; Peterson and Bartholomew, 1967; Sandegren, 1970; Gentry, 1970). As a result some population data are available for many breeding areas, but are limited to the three month breeding season. Thus, the movements of only the most thoroughly studied species, the northern fur seal, Callorhinus ursinus (Linnaeus, 1758), are at all well known (Kenyon and Wilke, 1953; Fiscus and Kajimura, 1966). Similar data on other pinniped species are incomplete or lacking.

The Northern (Steller) sea lion, Eumetopias jubatus (Schreber, 1776), breeds on land along the rim of the eastern Pacific Ocean from the Pribilof Islands (57° 15'N, Scheffer, 1958) south to Santa Rosa Island off southern California (33° 57'N; Bonnot, 1951) (Figure 1). Three distinct subspecies of the California sea lion, Zalophus californianus (Lesson, 1828), are recognized by Scheffer (1958): Z. c.

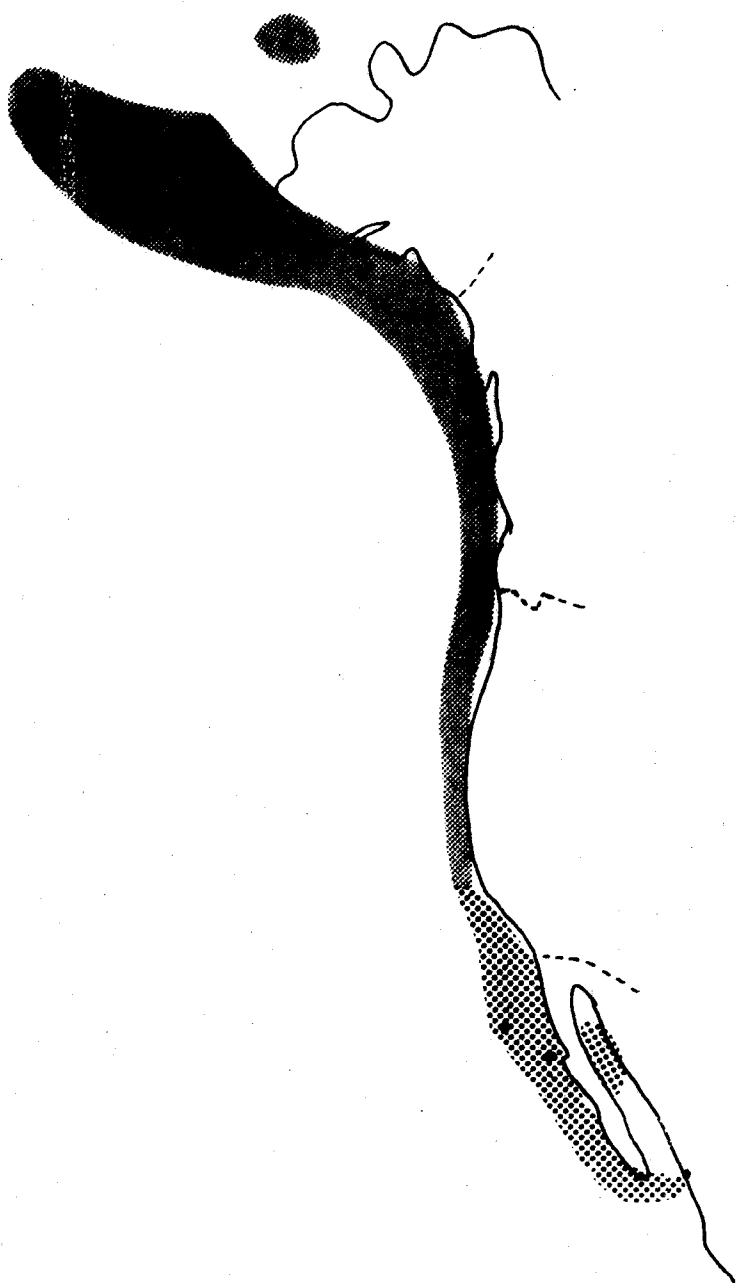


Figure 1. The breeding ranges of Eumetopias (■) and Zalophus (▨) along North America.

japonicus (Peters, 1866), limited to the Sea of Japan, may be extinct; Z. c. wollebaeki (Sivertsen, 1953), common to the Galapagos Archipelago; and Z. c. californianus (Lesson, 1828), found along the west coast of North America. Henceforth, Zalophus, as used in this text, will refer to Z. c. californianus only. This population breeds from Mazatlán, Mexico (23° 14'N) north to San Miguel Island (34° 03'N), the most northwesterly of the California Channel Islands (Peterson and Bartholomew, 1967) (Figure 1). Almost all behavior and population studies on Eumetopias have been carried out in Alaska, British Columbia, or California (e.g.: Pike and Maxwell, 1958; Mathisen and Loop, 1963; Sandegren, 1970; Gentry, 1970). Similar studies on Zalophus have been restricted to areas south of San Francisco, California (e.g.: Orr and Poulter, 1965; Peterson and Bartholomew, 1967). The purpose of this paper is to present data taken on the population fluctuations of Eumetopias and Zalophus along the Oregon coast from 1968 through 1971 in an effort to determine the migratory behavior of these species.

Except for population estimates developed by Kenyon and Scheffer (1962), Kenyon and Rice (1961), and Pearson and Verts (1970), no studies of Eumetopias and Zalophus have been made between Point Reyes, California, and Puget Sound, Washington. The scant information about the movements of these two species has been gleaned from sporadic censuses carried out by various investigators (Fry, 1939; Bonnot and Ripley, 1948; Bartholomew and Hubbs, 1952; Bartholomew and Boolootian, 1960; Kenyon and Rice, 1961; Orr and Poulter, 1965; Peterson and Bartholomew, 1967). This method, however, is not suitable for an

accurate assessment of migratory activities.

Geologic Evidence and Historical Aspects of Sea Lions in
the Eastern North Pacific Ocean

Geologic evidence indicates that sea lions similar to contemporary forms occupied the eastern north Pacific Ocean by the middle Miocene (Downs, 1956; Mitchell, 1967). The type specimen of one of the oldest pinniped forms (Desmatophoca oregonensis [Condon, 1906]), now in the University of Oregon Natural History Museum, was discovered west of Newport, Oregon in upper middle Miocene shales of the Astoria formation (Kellogg, 1922). Allodesmus kernensis, the oldest otariid fossil known, resembles Eumetopias in many respects (Downs, 1953). Pliocene and Pleistocene representatives of the genera Zalophus and Eumetopias are extremely similar to recent forms. The remains of sea lions found in kitchen middens and in fossil formations provide evidence of their importance to early North American cultures and give some indications of the former range of these mammals. Kitchen middens collected at Netarts, Oregon, in 1926 were supposed to have contained a few bone fragments of Zalophus (Bailey, 1936). A recent effort to locate these specimens in the United States National Museum, where they were reportedly deposited, was unsuccessful (Oltermann, 1972).

Early descriptions of pinniped populations and the behavior of these mammals on the west coast of North America were recorded by adventuresome travelers and captains of commercial ships. Among these accounts were those of J. A. Allen (1880), C. M. Scammon (1874), J. G.

During that time, these mammals were protected except around the mouth of Coos Bay, Elk River, Nehalem Bay, Netarts Bay, Rouge River, Sixes River, Tenmile Creek, Tillamook Bay, and Umpqua River. From May 1971 to December 1972, management of marine mammals was the responsibility of the Oregon State Game Commission, and all species were classified as non-game animals. Sea lions are now under the federal jurisdiction of the Department of Commerce and are protected species.

Mass kills of sea lions on their southern Oregon breeding areas had become a tradition according to local fishermen. No large scale raids were observed or reported during this study although several forms of harassment existed (e.g. people frequently shot from boats at sea lions that were on offshore islands).

Identification of Species and Terminology

Adult male Eumetopias reach four meters in length and weigh up to one metric ton, while the females are much smaller, reaching only 2.5 meters and 350 kilograms. The coloration of both sexes may appear a light buff, tan or a yellowish brown. Wet animals usually appear somewhat darker and some individuals occasionally appear silver. Adult males develop a massive, muscular neck and an associated thick pelage of long coarse hair often referred to as a mane. Newborn pups are approximately one meter long, weigh about 18 kilograms and are dark in color.

Zalophus males reach 2.5 meters and 300 kilograms, while the females demonstrate the sexual dimorphism common to most otariid species

to a lesser extent than Eumetopias, growing to two meters and 100 kilograms. Both sexes are dark brown when dry and appear black when wet. Males start to develop a noticeable sagittal crest during their fifth year, which easily distinguishes males over five years old from all other animals. Older males often have lighter colored hair in the area of the sagittal crest. The distinction between subadult males and females is quite difficult at a distance due to their similar size and skull structure.

Skull characteristics can be used to differentiate these two species. Eumetopias have a considerable gap between postcanines 4 and 5, while the cheek teeth of Zalophus are evenly spaced. A slightly developed sagittal crest is not diagnostic for Zalophus males, as Eumetopias males may possess sagittal crests as high as 4 centimeters and old Zalophus males often show an erosion of this skull feature.

Rookeries are areas occupied by breeding sea lions. Hauling areas are used by non-breeding animals of both sexes throughout the year. Rookeries and hauling areas may be adjacent to each other but distinctly separated, or the same piece of land at different times of the year. Both situations exist in Oregon (Figure 2). A population is a group of interacting individuals of the same species in a common spatial arrangement (Hanson, 1962). This definition has considerable flexibility; a population is not limited to a terrestrial location and need not consist of a stable number of individuals.

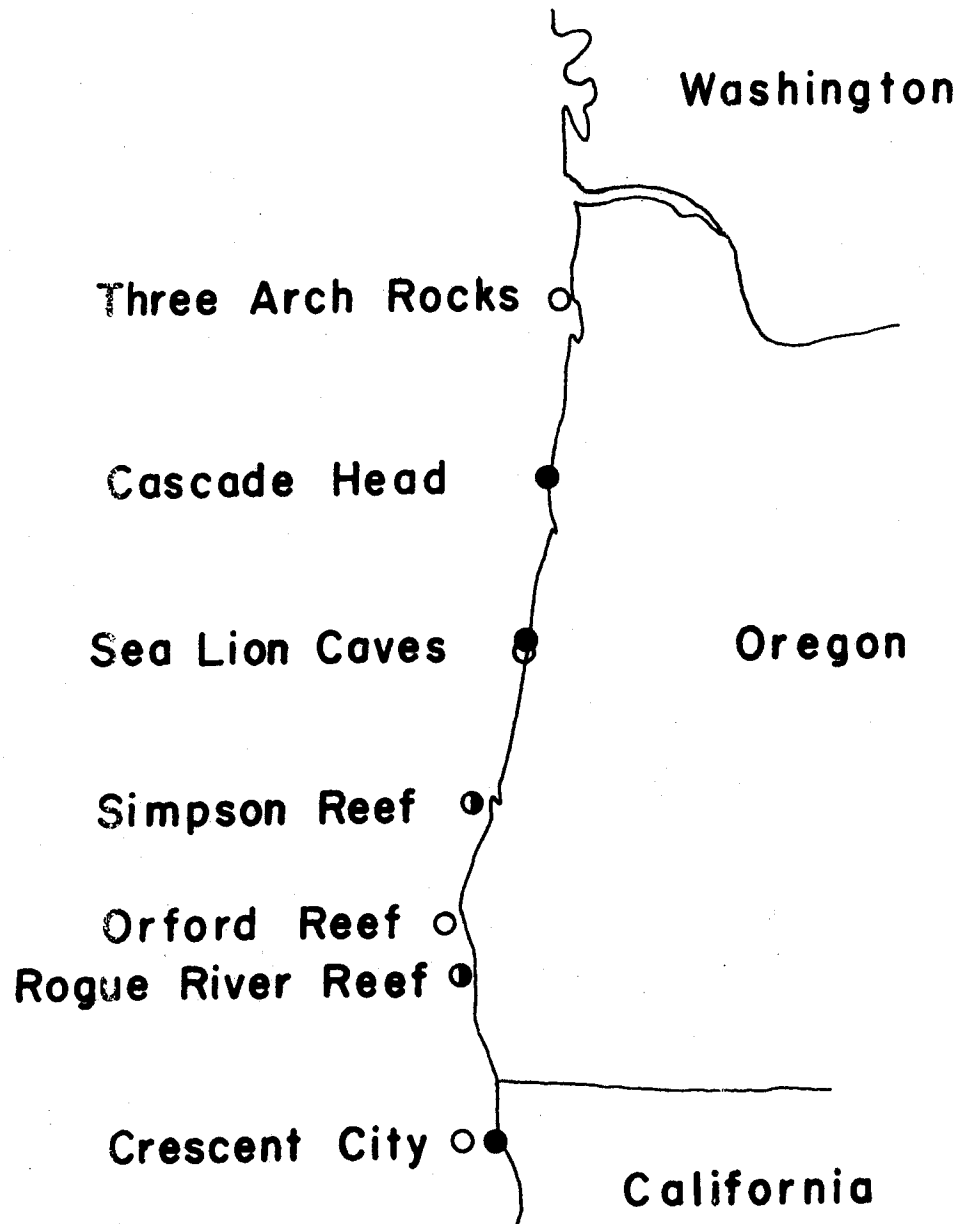


Figure 2. The locations of Eumetopias rookeries (○) and Zalophus hauling areas.(●).

Rookeries and Hauling Areas

The requirements of sea lions with respect to their selection of rookeries and hauling areas seem dependent upon several factors, some of which can be identified:

1. Man. That minimal human disturbance may be the most important qualification for a site is indicated by sea lions' preference for islands. These mammals use only two mainland areas in Oregon: Sea Lion Caves and Cascade Head (Figure 2).

2. Access to and from the water. This requirement is not as restrictive as it may seem because sea lions are very agile. They can, for example, leap up to a meter out of the water and land on a desired spot. More frequently, however, sea lions time their entry and exit from the water with the surf or swell. Rough seas actually give these mammals greater vertical mobility by allowing them to ride large waves up onto otherwise difficult places. The posterior slope of the body hair and more importantly the rough textured palmar surface of the fore-flippers provide adequate adhesion for sea lions to climb or remain stationary on very steep slopes. However, none of the commonly used access routes to rookeries or hauling areas in Oregon exceeds one vertical meter in height from the water at mean low tide. At some locations the lowest low tides occasionally make access to an area difficult.

3. Food. It has been suggested that a local abundance of prey species may be important to the choice of terrestrial habitats. Fishing immediately adjacent to many rookeries is excellent and an abundance of food may be some consideration for territorial bulls during the breeding

season at small rookeries (page 35), but no evidence was found to suggest that food was important in the choice of hauling areas.

4. Exposure and topography. Every rookery is at least partially protected from the prevailing winds and waves. Rookeries are usually on the leeward island of a group of islands (e.g. Rogue River Reef). Solitary islands are usually avoided. Areas not protected in coves or by other islands, usually slope to the water on the leeward side. Sea lions use the slope for access to the rookery or hauling area. Compared to hauling areas, rookeries are generally less rugged and are flatter.

Eumetopias are the only sea lions that breed in Oregon. The large rookeries of this species are maintained along the southern coast of the State, south of Coos Bay (Figure 2). Both Eumetopias and Zalophus, however, have hauling areas in Oregon (Figure 2). Crescent City, California, was used as the southern boundary of the study area because it was more natural for this purpose in terms of species distribution than was the Oregon-California border. The sea lion populations of northern California have not been studied; however, those of central and southern California have been studied extensively during certain times of the year (Fry, 1939; Bartholomew and Boolootian, 1960; Bonnot and Ripley, 1948; Carlisle and Alpin, 1966; Frey and Alpin, 1970; Odell, 1971).

The following descriptions of rookeries and hauling areas are in geographic order from south to north (Figure 2).

Crescent City. Non-breeding Zalophus males inhabit Castle Rock and the adjacent rocks off the south end of Runway 35 at Crescent City Airport. This aggregation may be the most northerly of this species during

its breeding season.

There is a solitary island hauling area of Eumetopias, located 1.2 kilometers southeast of the Crescent City Island Lighthouse and approximately 9.6 kilometers west of Crescent City.

Rogue River Reef is 4.8 kilometers northwest of the mouth of the Rogue River and the town of Gold Beach. The islands of this group support the second largest Eumetopias rookery in Oregon.

Orford Reef lies 9.6 kilometers northwest of Port Orford and 6.4 kilometers southwest of Cape Blanco. Eumetopias breed on three islands of this group.

Simpson Reef, located in the north cove of Cape Arago State Park, is 8 kilometers southeast of the mouth of Coos Bay. A small breeding population of Eumetopias uses the reef. The rocks protected by the reef constitute the largest hauling area in the state for Zalophus.

Sea Lion Caves, a well managed tourist attraction 12.8 kilometers north of Florence, is primarily a year around hauling area for Eumetopias. The animals use an exposed rocky ledge and a large natural cave seasonally. Sporadic breeding occurs there without stereotypic territory maintenance.

Zalophus haul out in a small cove and cave 0.4 kilometers north of Sea Lion Caves.

A Zalophus hauling area is located on Cascade Head, a rugged natural headland. Until recently, an undeveloped trail providing human access to this rocky beach was not well known, and the area has been relatively undisturbed.

Small groups of Eumetopias occupy Three Arch Rocks, 1.6 kilometers northwest of Oceanside throughout the year. The breeding status of this population is unknown.

The islands just off-shore at Ecola State Park, south of Tillamook Head are occupied by a few Eumetopias during the breeding season, but the breeding status of the animals is unknown.

Three Arch Rocks and Ecola State Park may be established rookeries, but because of their small size are probably insignificant. These areas are used as hauling areas predominantly by Eumetopias during the winter.

CHAPTER II

METHODS

Collection of Population Data

An extensive search of the literature was carried out to determine what was known about marine mammal migrations and field study techniques. Although many of the methods and devices employed by other investigators to determine population movements were appealing, they were also expensive. Budget limitations ruled out telemetric devices, extensive offshore collections of specimens, and long-range tagging programs. However, several suitable alternatives were suggested. Recognition of individual animals is the basis of most tagging programs. Characteristic scars, coloration and abnormalities, rather than tags, can be used to identify individuals.

Unique features of each animal were drawn on a card and then filed by major characteristics. During the first two years of the study, 1968 and 1969, several animals were marked with dyes and bleaches. None of the artificial marks was visible longer than seven months.

Population data was gathered by censusing. The location, sex, and species of animals, as well as time, weather, and ocean conditions, were recorded during each census of an area. Daily census information was obtained regularly for only two areas: Simpson Reef and Sea Lion Caves.

Most counts of animals and pertinent weather information at Sea Lion Caves were made and recorded by the management. Spot checks indicated that their counts were reliable. During the summers of 1968 and 1969, the sea lions on Simpson Reef were censused three times daily using 20X field glasses and a 15-60X spotting scope. Sea lions using this area during the late fall, winter, and spring of 1968 and 1969 were counted at irregular intervals. From the spring of 1970 through 1971, the animals were censused with regularity.

Censusing of major rookeries was limited by the expense and time required to reach most offshore areas. However, an effort was made to visit each rookery at least once, and usually twice during the breeding season to assess its population characteristics. A boat was used exclusively during 1968 and 1969 to reach the islands occupied by sea lions. Access to all but one of these sites (Crescent City-Castle Rock) was achieved without disturbing the resident population. The animals were most easily counted from high points on the land or islands. Estimates obtained as a result of these counts are considered conservative because some areas were not visible from the counting positions and some animals were probably in the water. Regular censusing of all areas was limited to autumn, when it was established that rapid fluctuations in numbers and species composition occurred.

The use of aircraft in 1970 and 1971 made censusing easier and allowed unobscured observation of entire areas. Although expensive, aerial surveys were superior in many other ways. They provided a conservative estimate of sea lion populations along the entire coastline

from Crescent City, California to Astoria, Oregon, in a single day. The chance of counting an individual more than once was remote. The opposite was true in obtaining counts from the ground because the animals had sufficient time to move before the count was finished. Aerial photographs provided a permanent record of entire island populations during aerial surveys. A Nikkormat FTN 35 mm camera with a 50 mm, f/1.4 lens was used to photograph populations from a Cessna 150 or Cessna 172 airplane at an altitude of 65 to 125 meters. Good resolution was obtained with fine grained color film, which permitted accurate counts of sea lions from photographs. Although close range photographs were adequate for species determination, sex and age were often difficult to discern. A more accurate estimate of these characteristics was obtained by flying repeatedly over the area at low altitudes. On-site visits to the areas produced the most accurate estimates of sex and age distribution.

The Oregon State Game and Fish Commissions made available considerable data during 1970 which they had obtained from public reports of sea lions observed on private or public property in unusual locations.

Behavioral Observations

Behavioral data were collected by visiting the rookeries and hauling areas to observe animals at close range. Field observations were made day and night from distances up to 20 meters. Limited information on breeding behavior was collected and is compared in this

paper with data taken by Sandegren (1970) in Alaska and by Gentry (1970) at Año Nuevo Island, California. Little documentation of behavior outside the breeding season was found in the literature. Changes in the behavior of Eumetopias and Zalophus were noted during the non-breeding season, especially during periods of cohabitation in autumn, and were compared with the observations of Orr and Poulter (1965).

Specimen Collection and Biomedical Procedures

Skulls and bacula were collected from dead animals found along the beach. Animals were also killed during the study (under permits from the Oregon State Fish Commission by authority of ORS 509.185 and from the Oregon State Game Commission-permit No. 5686, by authority of ORS 497.780) to obtain data on age composition, feeding habits, parasites, certain clinical norms, and chlorinated hydrocarbon and heavy metals concentrations in various tissues. The animals were shot in the neck with a high powered rifle. Blood samples were collected from major arteries in the neck using double strength heparinized Vacutainers,^R often in combination with various preservatives for subsequent laboratory analysis. Major clinical parameters were analyzed using hospital laboratory equipment and will be reported elsewhere. The following samples were removed from sacrificed specimens to determine chlorinated hydrocarbon and heavy metals concentrations: hair, blubber (fat), skeletal muscle, heart muscle, liver, kidney, bile, pancreas, and sections of brain. The tissues were analyzed at the Environmental Health Sciences Center, Oregon State University, in cooperation with

Drs. Donald Buhler and Robert Claeys. Data obtained as a result of these analyses will not be presented here, but will be published later (Mate et al., in press). Information on feeding habits was obtained from the stomach contents of sacrificed animals. The contents were sorted into such identifiable components as otoliths, cephalopod beaks, and the remains of crustaceans. Invertebrates were identified with the aid of Light et al. (1967), and fish otoliths were dried and sent to Mr. John Fitch, California Department of Fish and Game, for identification. Detailed data on prey species will be reported elsewhere; however, the time of feeding is discussed as it relates to population movements (page 26) and general food preferences are compared with previous findings as a possible motive for migration (page 31). The ages of all animals were determined from dental annuli (Scheffer, 1950; Fiscus, 1961; Orr et al., 1970) using a new technique employing an acetate peel (Mate and Orr, submitted).

CHAPTER III

POPULATION KINETICS

Diurnal Population Fluctuations

The number of animals found on a rookery or hauling area changes daily as well as seasonally. An understanding of daily fluctuations in numbers of animals on an area is extremely important to the accuracy of a census. During the summers of 1968 and 1969 the sea lions on Simpson Reef were counted three times daily. This censusing scheme was carried out only sporadically throughout the rest of 1968 and 1969. Daily censusing was conducted during periods of good weather and mild seas throughout 1970 and 1971.

The data suggest that four major factors influence daily population fluctuations, and may produce longer effects: (1) time of day, (2) weather, (3) ocean conditions, and (4) human disturbance.

1. Time. Continuous censusing revealed a marked midday peak in the population of breeding Eumetopias hauled out on Simpson Reef. Similar midday population patterns have been observed for breeding Eumetopias by Sandegren (1970) in Alaska and by Gentry (1970) in California. Kenyon and Rice (1961) recorded the only instance of such diurnal patterns for Eumetopias outside the breeding season. They made 31 counts on a small population in Alaska between mid-February and mid-

May; however, 14 of these were during storms. The mean number of animals on land during 7 afternoon observations was greater than the mean number during 10 morning observations. Figure 3 shows the daily population pattern for male Zalophus during the non-breeding season. The pattern may be altered by the factors discussed below. Regular censusing of areas was therefore conducted during midday when the populations were at a maximum to approach the true population value for each area.

2. The influence of weather on daily population patterns. Certain weather conditions can alter the basic midday peak pattern of sea lion populations. Although population changes are apparently unrelated to temperature changes, sea lions, like other mammals, change their postural positions presumably to conserve or dissipate heat. Various investigators have noted a shift in the positions of Eumetopias (Gentry, 1970) and Zalophus (Peterson and Bartholomew, 1967) toward the water or into it as a result of high ambient temperatures and/or intense solar radiation. It is interesting to note that Zalophus is much darker than Eumetopias but has a more favorable ratio of exposed surface area to volume for the dissipation of heat. These factors suggest that Zalophus probably absorbs more heat per unit area than Eumetopias but can dissipate it better because of its smaller body size. The dissipation of heat is probably an asset to Zalophus in its more tropical distribution. Behavioral thermoregulation in both sea lions appears to be the same. When the animals seem to be suffering from the heat, they generally move into or closer to the water. Heat is lost by conduction into the water or the moist substrate at the water's edge. Zalophus are well known to

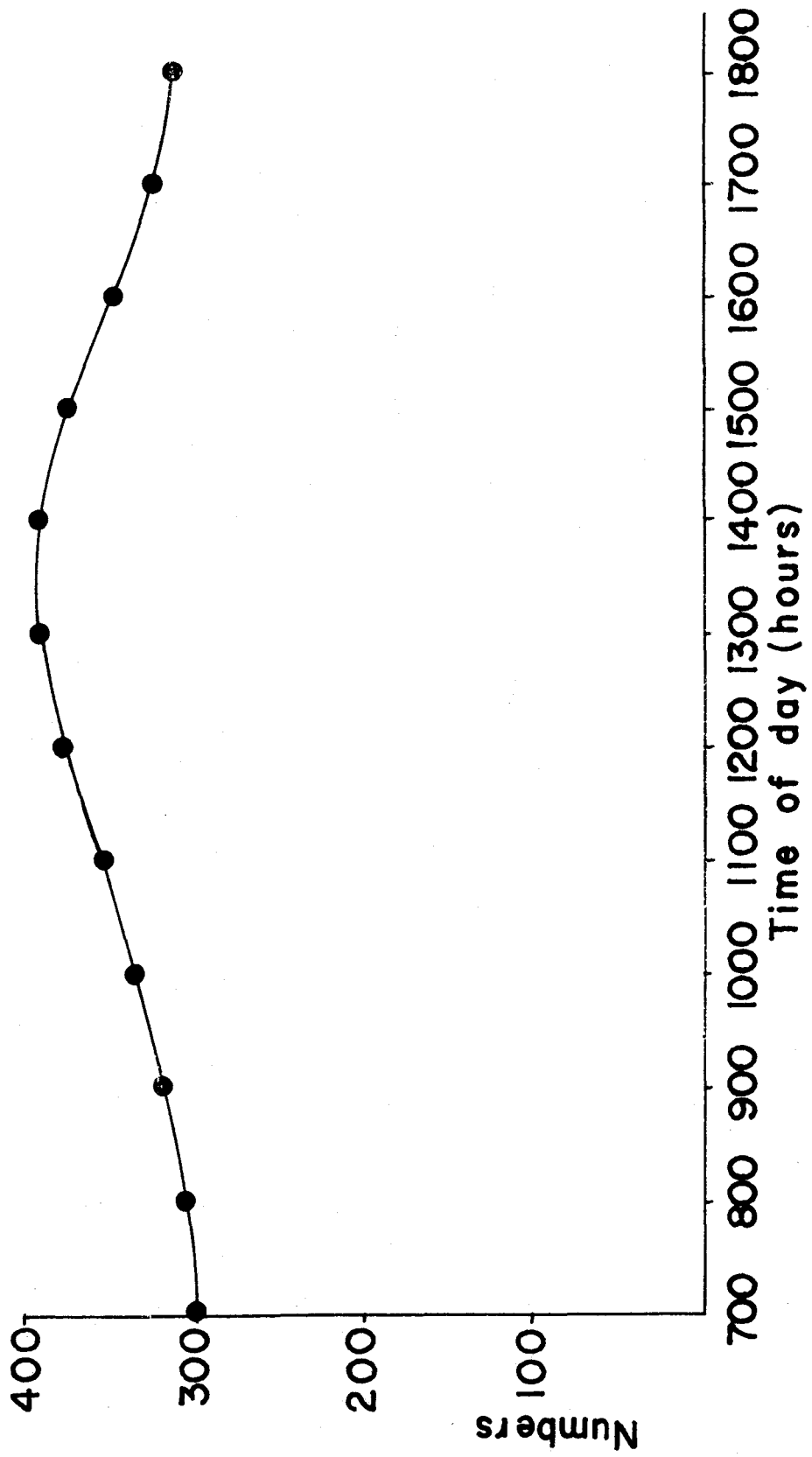


Figure 3. Daily population fluctuations of male Zalophus

stay near the water's edge during warm weather. Wet animals also lose heat through evaporative cooling. Neither sweating nor panting seem to be effective cooling mechanisms for Zalophus (Whittow et al., in press). Oregon ambient temperatures are mild by comparison with those of southern California, where both species can be found during the summer. During the summer, the warm air over the land on the Oregon coast pulls cool Pacific marine air toward land. This air conditioning effect produces very mild year-around temperatures on the offshore rocks and along the shoreline. Record high temperatures for the southern Oregon coast (in degrees Fahrenheit) for June, July, and August (1933-1963) are 86°, 84°, and 84°F respectively. Mean daily minimum and maximum temperatures for the same months are: June, 50° and 64°; July, 51.9° and 66.1°; and August, 51.9° and 67.2° (U.S. Dept. of Commerce, 1963). Ambient temperatures recorded at offshore areas frequented by sea lions averaged 8°F lower than those taken ashore in the same area. Therefore, it is unlikely that sea lions suffer from excessive heat due to normal air temperatures in Oregon. During the summer, solar radiation may cause some discomfort for the animals directly or by elevating substrate temperatures where animals reside on dark rocks. Substrate temperatures were not taken during this study, although sea lions were observed to avoid some areas with dark substrate during the summer.

The most reproductively active Eumetopias males were those with semi-aquatic territories (territories along the water's edge or with tide pools replenished frequently by the surf). Similar relationships have been shown for Alaska (Sandegren, 1970) and California (Gentry,

1970) populations of breeding Eumetopias. The thermoregulatory value of semi-aquatic territories in Oregon is questionable because of mild temperatures. These locations may be advantageous for breeding males merely because females must pass through these areas to enter the water or haul out. In southern California, however, semi-aquatic territories may play an important role in the thermoregulation of Eumetopias and Zalophus.

Neither species avoids mist from breaking waves or light rain. During the non-breeding season, however, Eumetopias and Zalophus enter and remain in the water during periods of heavy rainfall or when large ocean swells throw considerable spray over their hauling area. This behavior was not observed for breeding Eumetopias because such weather conditions rarely exist during the summer.

3. Ocean conditions. As mentioned above, sea lions avoid the very heavy spray of large swells and always abandon an area if it becomes awash. Periods of inclement weather and associated rough seas send almost every animal into the water, and the pre-storm population numbers are usually not reached until after several days of calm weather. The tide affects the ease with which these mammals enter and exit from some landing areas but has an even greater effect on certain areas within the tidal zone used by sea lions. Parts of the Crescent City hauling area, Simpson Reef hauling areas, and the cove to the north of Sea Lion Caves are covered by tides of sufficient height causing the animals on these areas to seek higher ground as the water level rises. Animals in this situation crowd together until they cover all available space,

eventually resulting in a three dimensional crowding. Animals displaced by the rising tide usually enter the water and haul out almost immediately by climbing over individuals at the water line and finding a spot on top of others.

4. Human disturbance. The low tide at Cape Arago is an indirect cause of rather dramatic population changes during the non-breeding season. Any tide lower than +.4m. allows human access to sea lion hauling areas. Human disturbance has some immediate as well as long term affects. With adequate care, it is possible to approach sea lions very closely, a feat frequently accomplished by photographers, biology students, and tourists every year. Unfortunately, all visitors are not satisfied with a good close look and like to watch or photograph the animals in flight. An unusual noise or a moving erect silhouette may scare one animal, whose distinctive vocalization may alarm the entire population into a stampede for the water. The majority of the animals may not even be aware of the source of danger. If the group has not been disturbed recently, the flight reaction is more often limited to animals in the vicinity of the sea lion who voiced the warning or to younger animals. Similar reactions can also be caused by the scream of an alarmed gull or the sharp report of a suddenly surprised harbor seal smacking the water with a foreflipper. Falling rocks, gun shots, and helicopters also frighten the animals, although fixed wing aircraft have no apparent affect on sea lions unless they pass repeatedly at low altitude. If a flight reaction is not immediate or if the animals stop short of the water, all individuals look about for the source of danger.

Satisfied that there is nothing to fear, they usually settle back to their resting postures. If a further disturbance occurs while the animals are looking for possible danger, the whole population immediately enters the water. Zalophus and Eumetopias are very sensitive to movement. Less than 50 percent of a population disturbed by humans returned to the same general area the same day. After several days of low tides coupled with human disturbance, the number of animals hauled out did not return to that area's seasonal norm for at least four days (Table 1). Frequently disturbed sea lions may abandon an area, although cases are known where animals tolerate or ignore the close presence of humans, e.g., Zalophus on the Monterey, California, breakwater and Z. c. wollebaeki in the Galapagos Islands. Apathy toward man is typical of some pinniped populations on isolated islands and in polar regions not accustomed to the regular presence of man.

TABLE 1. The prolonged effects of human disturbances during low tides on the population of male Zalophus at Simpson Reef.

Pre-disturbance population	Post-disturbance population (% of pre-disturbance population)					
	same day	1 day later	2 days later	3 days later	4 days later	5 days later
255	92	119	148	195	221	240
284	68	98	127	175	257	293
240	119	160	192	224	210	247
278	126	159	203	187	237	285
256	44	109	165	217	221	246
263	92 (35%)	129 (40%)	167 (63%)	200 (76%)	229 (87%)	270 (103%)

To summarize, a more accurate census (counting a greater number of animals) is most likely if the counts are made: (1) at midday, (2) on a slightly overcast day with mild temperatures and low wind after several days of good weather, (3) when the oceans are calm (and high tides are avoided). Without continuous observation, it is impossible to determine whether an area has been visited recently by humans. Censusing of areas where low tides provide human access should be done at least four days after access is no longer possible.

Daily Population Fluctuations and Feeding Behavior

Individuals of both species were seen leaving their respective rookeries and hauling areas in the late afternoon; these animals formed species-specific aggregations within 100 meters of these areas. During the build up of these aggregations, participants swam about in a tight group and stayed in one location close to the surface weaving in and out among one another. When a group finally departed, all individuals moved as a tight unit in one direction at a uniform speed. Nothing has been found to suggest what motivates the group to leave at some particular time. The groups observed in Oregon ranged in number from 2 to 38 (mean of 14) among a population of 500 sea lions along the southern coast. Larger groups were seen near Sea Lion Caves but very little data was collected there on the timing and ultimate destination of such groups. These Oregon groups cannot be compared with the "large" groups meticulously observed by Gentry (1970) in California (mean number of individuals = 4) or those observed by Fiscus and Baines (1966) in

Alaska containing several hundred to several thousand because of the different techniques each investigator used and the different population size observed.

Single animals land on the rookeries and hauling areas throughout the day. The difference between landings and departures is greatest during the morning (Figure 4). This behavior pattern is responsible for the midday peak noted previously (Figure 3). Initially, it was not known if individuals landing in the morning were those that had departed the previous evening. Close observation of identifiable animals, however, determined that such was the case (Table 2). Of those Zalophus observed leaving the hauling area within 2 hours of sunset (and not returning before sunset), 89 percent returned the following day by noon. This pattern appears contrary to that observed by Fiscus and Baines (1966) for Eumetopias in Alaska. There, the animals left their hauling grounds early in the morning and returned in early evening, feeding 8 to 24 kilometers at sea in the interim.

To determine if daily population fluctuations were related to feeding, 16 male Zalophus were collected as they hauled out of the water shortly after sunrise. Fourteen (88%) had full stomachs, whereas only 3 (21%) of 14 stomachs from animals taken at random during midday contained food. These results are notably different from those obtained by Mathisen et al. (1962), who found no significant difference in frequency of food within the stomachs of animals collected as they hauled out of the water and stomachs of those already on land. Mathisen, however, omitted from his collection analysis time considerations which could be

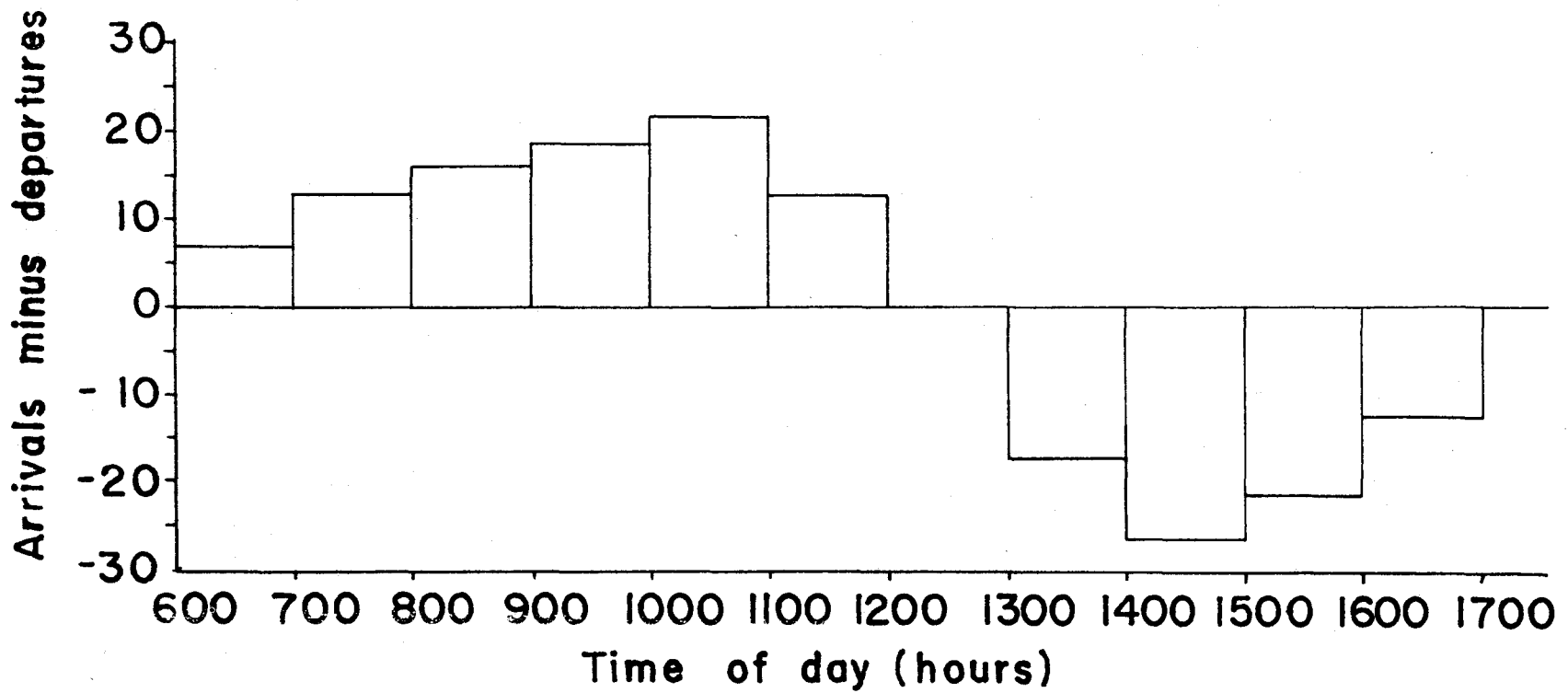


Figure 4. Hourly differences of arrivals minus departures for a population of 400 male Zalophus

TABLE 2. Data illustrating that many male Zalophus leaving the hauling area in the evening return the following morning.

	20 Sept. 1969	29 Sept. 1969	13 Oct. 1969	16 Oct. 1969	19 Oct. 1969	Average
A Animals observed leaving within 2 hours of sunset	104	116	95	89	121	105
B Animals from group A observed returning before sunset	43	73	40	21	48	45
C Animals from group A not returned by sunset	61	43	55	68	73	60
D Animals from group C returned by sunrise	23	17	29	24	36	26
E Percent D of C	38	40	53	35	49	43
F Animals from group C returned by 2 hours of daylight	46	35	41	47	59	46
G Percent F of C	75	81	75	69	81	76
H Animals from group C returned by midday	55	40	49	57	64	53
J Percent H of C	90	93	89	84	88	89
K Animals from group C not returned by midday	6	3	6	11	9	7
L Percent K of C	10	7	11	16	12	11

crucial if animals that haul out during early morning hours have just returned from feeding. It may even be expected that animals hauling out later in the day would be less likely to have food in their stomachs if individuals eat at night, haul out in the morning and remain on land while digesting their food. Random collections made by Mathisen et al. (1962) showed 27 percent of the animals contained food. This percentage agrees closely with that (21%) of the small sample taken in this study. Of the animals collected at random in the evening only 1 (7%) of 14 stomachs contained food. Table 3 summarizes the feeding data.

TABLE 3. Winter feeding data for Zalophus in Oregon

Sample Time	Morning ¹	Midday ²	Evening ²
Sample size	16	14	14
Number (%) with fresh food in stomach	12 (75)	1 (7)	1 (7)
Number (%) with digested food in stomach	2 (13)	2 (14)	0 (0)
Total: Number (%) of stomachs with food	14 (88)	3 (21)	1 (7)

¹Animals killed just as they were hauling out.

²Animals killed at random on the hauling area.

Sea lions have very strong digestive enzymes and acids which continue to degrade food very quickly even after the stomach is removed and frozen. Immediate inspection of stomach contents is important if the degree of digestion is to be ascertained. The data suggest that Zalophus is predominately a nocturnal feeder. The sample obtained in

the morning was biased because the animals were not taken at random. A random morning sample would certainly be interesting for comparison. Another sample of interest would be from animals landing during the mid-day and evening. The fact that sea lions taken during the midday and evening contained food (and especially those that contained fresh food) indicates that these animals are not strictly nocturnal in their feeding habits.

Individuals which left during the evening and were observed landing the following morning were assumed to have fed during the night. The time between nocturnal "feeding trips" varied from two to eight days. Both ends of this range may be in error for two reasons: (1) an animal may have been considered to have been on a trip when in reality it had only changed its position during the evening and again the following morning (there was no way of determining this type of error), and (2) by failing to see an animal leave and return. The first type of error is probably made less frequently than the second, but would bias the data toward the low extreme, whereas the second would emphasize the high range. The mean number of days between "feeding trips" was 4.2 days ($n = 18$).

During their pelagic fur seal studies, Fiscus and Baines (1966), observed Eumetopias feeding during the day at a distance 8 to 136 kilometers offshore and also saw a Zalophus 62.4 kilometers from shore. They collected a 6 year old female Eumetopias 41.6 kilometers west of Yaquina Head, Oregon. Although offshore observations were not planned for this study, a few individuals and very rarely a small group of each

species were observed from the air within 2 kilometers of the coast during the day. If food is the objective of nocturnal trips away from the hauling area, it would appear that the animals are either having difficulty locating food close to shore or they normally swim offshore some distance to obtain their prey. Food in the stomachs of animals collected in the early morning is usually fresh or only partially digested (Table 3), indicating that the fish were recently caught or that the digestive process is delayed while swimming.

Zalophus have long been considered to feed primarily on squid, Loligo sp., and small fish such as anchovy, Engraulis mordax, because of the high frequency of both genera in Zalophus stomachs (Evermann, 1921; Bonnot, 1928; Scheffer and Neff, 1948; Fiscus and Baines, 1966). However, previous studies have reported on Zalophus collected almost exclusively in southern California during the summer months when a seasonal abundance of both prey species is known to occur. If Zalophus exhibited a feeding preference to these species year around, it might be expected that Zalophus migrate to follow this resource. This does not appear to be the case; Zalophus stomachs, taken during the fall and winter in Oregon, contained larger fish almost exclusively (Mate, unpublished data). Squid are not harvested commercially along the Oregon coast except inadvertently during shrimping operations; therefore, little is known about their distribution and abundance in this area. However, packing plant operators and drag boat captains in the Coos Bay area do not believe that this species is abundant during any season and that concentrations here are definitely lower than those of southern

California. Anchovy, though seasonally common during the summer in several Oregon estuaries, is available in great numbers only from the Chetco River, near the Oregon-California border, and south (Mager, pers. comm.). Studies conducted by the California Department of Fish and Game (Haugen et al., 1969) indicate that a small portion of those anchovy tagged and recovered at various areas in southern California subsequently moved as far north as Monterey. Additional information on the movements of anchovy is not now available. However, it seems unlikely that anchovy from southern California move en masse as far north as Oregon because the seasonal abundance appears to coincide in both states. The anchovy population is conservatively estimated at 4 to 5 million tons, 50 percent of which occurs off California. Catch records of anchovy indicate that this species is abundant in California waters throughout the fall, winter and spring (Messersmith, 1969; Pinkas, 1970). Therefore, it is unlikely that Zalophus migrate to follow anchovy or squid. This does not eliminate other prey species as motives for migration.

Seasonal Population Fluctuations--1968 and 1969

Eumetopias

Because two species of sea lion are found along the Oregon coast, seasonal data will be given in chronological order beginning in late spring when only Eumetopias is present in substantial numbers.

Breeding males arrived on the rookeries in mid-April and early May, although individuals were seen in Oregon as early as late March. Some

females wintered in Oregon and were on the rookeries when the males arrived. A population wave of females was distinguished moving south during March and April (Figure 5). Most of the breeding females had landed by late May after the males had established their territories. The females gave birth to single pups usually within a week after their arrival. The peak of pupping occurred during the first week in June. Females came into estrus several days after pupping and mated with a territorial male. The ratio of territorial males to females varied from year to year and from rookery to rookery. On smaller rookeries, such as Simpson Reef, the ratio ranged from 1:10 (1969) to 1:17.3 (1970). The ratio on larger rookeries, such as Orford Reef, was consistently lower and less variable at 1:5.6 (1969) to 1:8 (1971) (see Appendix I, page 68).

During the breeding period, individual females left the Simpson Reef rookery every three or four days in the evening, presumably to feed, and returned the following morning. On large rookeries, each male tended to maintain a short but continuous vigil over his territory. Fourteen males on large rookeries were observed to hold their territories from 2 to 14 days, with a mean of 7.7 days. Twelve of these males willingly abandoned and did not reclaim their original territory; several were subsequently observed taking up other territories or hauled out on adjacent non-breeding areas. Two males were forcefully evicted from their territories by other males. Both of these animals had been on their territories only a short period (2 and 3 days) and perhaps were not "fully established" when challenged. The lack of food

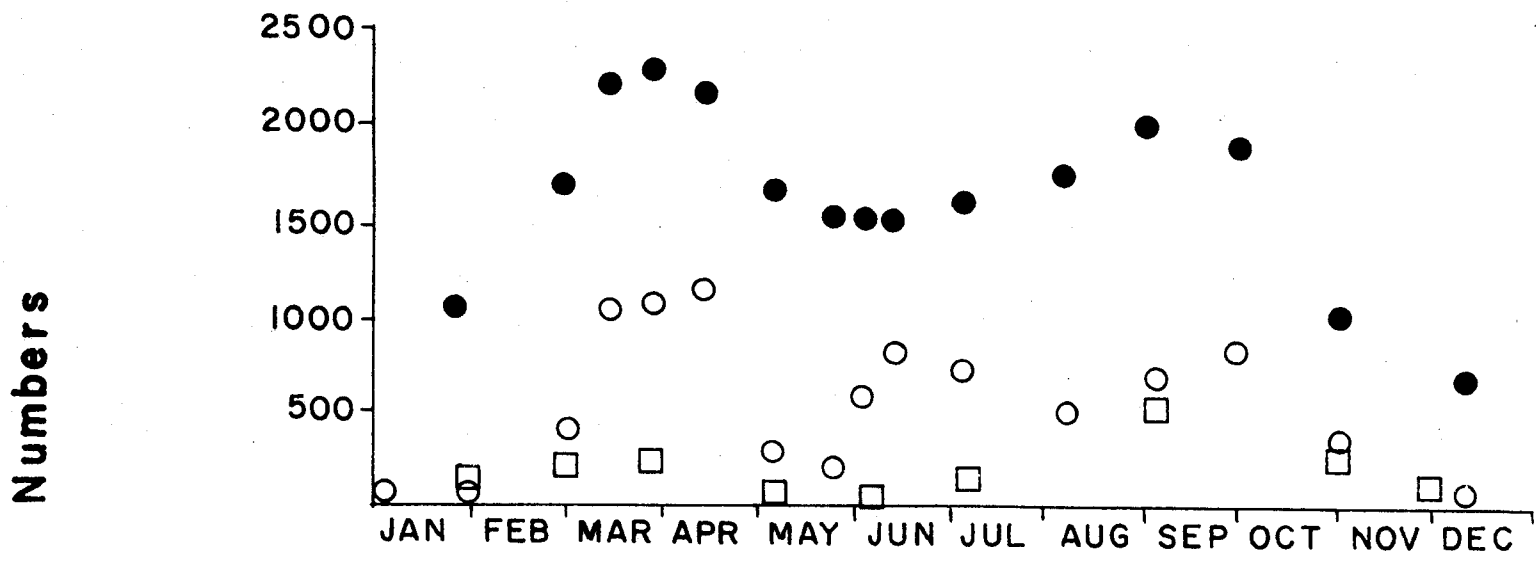


Figure 5. Seasonal fluctuations of female (●), pup (○) and subadult Eumetopias populations along the Oregon coast.

or water, which is believed by some investigators to be a metabolic by-product of digestion (Pilson, 1970), may be why the males did not maintain their territories for longer periods. On small rookeries where available space apparently limits the number of territories, territorial males occasionally left individually during the evening for as long as 6 hours. However, most males were absent an average of 1.2 hours and may have spent their time feeding close to the rookery. In each case observed, the male returned to his still vacant territory. Perhaps unattended territories on small rookeries were ignored because of: (1) a lack of bachelor bulls in the vicinity and (2) a mutual recognition of well defined territories by adjacent territorial males which prevented encroachment during the short absences of a male.

Males on small rookeries were not observed to lose weight nor become emaciated, suggesting that these males may feed periodically during their relatively long territory maintenance (mean of 32 days). This hypothesis was at least partially substantiated late in the 1969 breeding season when the largest and most active territorial male at Simpson Reef was killed by sports fishermen. The stomach of that animal contained four large octopus beaks, but no fish remains. Octopus is common in this rocky intertidal area and can be found both inshore and offshore. However, Fiscus and Baines (1966) noted that the beaks of octopus and squid may persist in the stomach during several subsequent feedings on small, fragile fish species.

Mating reached a peak during the last two weeks of June and was completed by mid-July, at which time breeding males discontinued

maintenance of territories. The schedule of territory establishment, pupping, and breeding among Eumetopias in Oregon parallels that found for this genus in other parts of its range from southern California to the Bering Sea.

Few subadults were present during the breeding season, but became numerous as the territorial male disappeared (Figure 5). Many subadults tagged in central California were later seen in Oregon, indicating a northward movement of these age classes. Some subadult males assumed territories where females and pups were present, after breeding males had left. These animals, however, were usually ignored by the females and pups and none were observed to breed. The post-breeding season influx of subadult males coincided with a substantial increase in the number of adult males which had not bred in the immediate area. These animals used hauling grounds and rookeries, and did not display territorial or breeding behavior. Some of the new arrivals were easily identified as adult males previously observed breeding on more southern rookeries in Oregon (e.g., a male observed in early August at Sea Lion Caves bred at Rogue River Reef during June), suggesting that these animals moved north following the breeding season. This hypothesis is substantiated by the lack of adult males at Año Nuevo Island, California by the end of August (Orr and Poulter, 1967; Gentry, 1970).

Zalophus

Zalophus also breed in the spring, although further south than Eumetopias. Peterson and Bartholomew (1967) discuss the breeding

behavior of Zalophus and state that the breeding range extends from Mazatlán, Mexico (23°N) north to San Miguel Island, California (34°N) (Figure 1). However, dead pups were found during the 1968 breeding season at Lion Rock, California (35°N) (Peterson, pers. comm.), where Bonnett (1928) observed the northern-most rookery of this species. During the breeding season, aggregations of non-breeding adult and sub-adult males were found in the study area at Crescent City, California (Figure 2) (41°46'N), well north of the breeding range. Females have not been recorded north of Año Nuevo Island, California (37°N) (Morejohn, 1968); and none were positively identified within the study area.

Following the breeding season, the males are known to move northward as far as Año Nuevo Island, California (Orr and Poulter, 1965). The northward movement of this species was first hypothesized by Fry (1939) who observed surprisingly large numbers of Zalophus in southern California during the winter and suspected that these individuals had moved there from Lower California. Bartholomew and Hubbs (1952) found few adult males on the San Benito Islands (28°N) during the winter. Bartholomew and Boolootian (1960) indicated that the winter population of bulls on the California Channel Islands exceeded the summer population; the opposite was true with respect to the females.

The hypothesis that has developed as a result of these studies is: Zalophus (and Eumetopias) males move north in the winter and south in the summer while many of the females and immature animals move south during the winter and north during the summer (Bartholomew, 1967). Proponents of this theory have previously overemphasized the report of

Cowan and Guiguet (1956:350) ". . . only two official specimen records exist for British Columbia, west coast fishermen inform us that California sea-lions occur almost every winter in Barkley Sound on southern Vancouver Island." Whereas Cowan and Guiguet properly labeled the information related to them as hearsay, they have been cited by other authors as confirming the regular winter occurrence of Zalophus in Barkley Sound. The paper in question reports two specimens, but presents no proof of regular occurrence and makes no such claim. The regular occurrence of small numbers of Zalophus in British Columbia has recently been confirmed (Pike and MacAskie, 1969; Hancock, 1970). Bigg (in press) is preparing more extensive information and numerical data on several hauling areas along British Columbia, the largest of which, Folger Island, supports 400 individuals.

Why some males move as far north as British Columbia and others stop at or remain in the California Channel Islands is unknown. The timing of massive post-breeding movement of Zalophus into Oregon was consistent during the course of the study (Figures 6-8). While individual Zalophus were first seen on Simpson Reef as early as July, they were not present in numbers until mid-August. The number of animals increased steadily, reaching a peak early in October. The population then declined sharply, stabilized for a while, and gradually declined during the winter and spring. A similar pattern was observed on all hauling areas used by Zalophus within the study area. The movement of males between hauling areas was documented during 1969. Frequent counts of animals on all areas within the study area during the fall of that

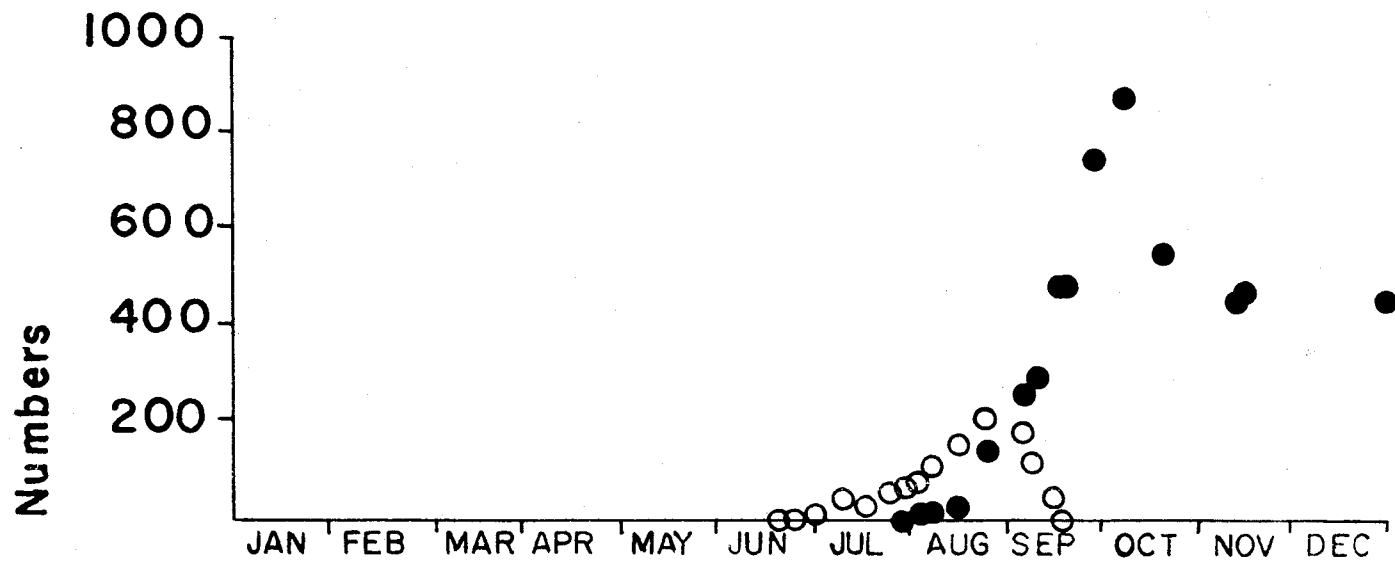


Figure 6. Male Eumetopias (○) and male Zalophus (●) at Simpson Reef during 1968.

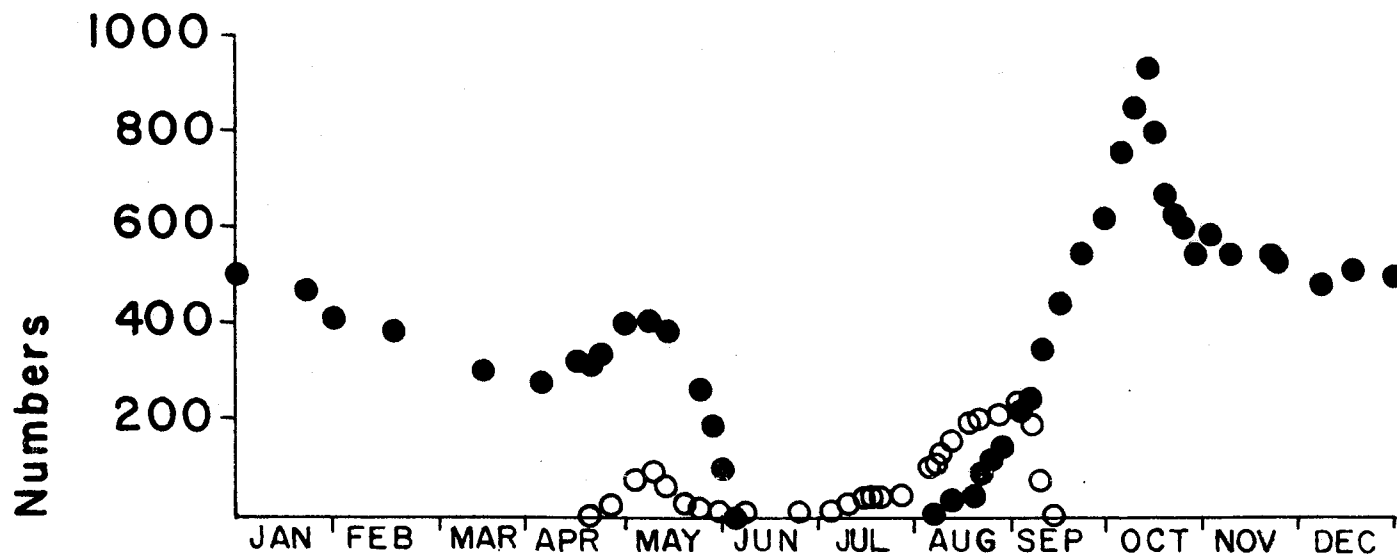


Figure 7. Male Eumetopias (○) and male Zalophus (●) at Simpson Reef during 1969.

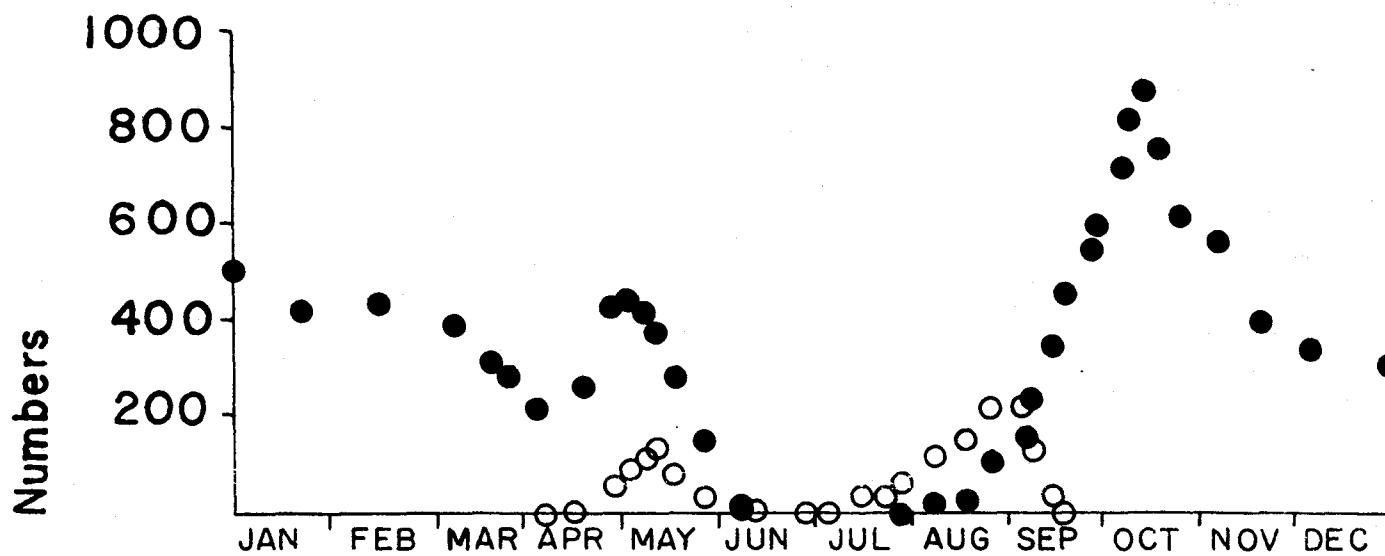


Figure 8. Male Eumetopias (○) and male Zalophus (●) at Simpson Reef during 1970.

year revealed a well ordered northward movement of Zalophus along the Oregon coast. Although factors influencing the presence or absence of sea lions were taken into consideration before censusing, individual census points may not accurately reflect the true population numbers for a particular area. More frequent counts might have produced more accurate information.

However, the population peak for Zalophus at each hauling area (from south to north), when plotted with respect to time and distance, reveals a straight line (Figure 9). This suggests a movement from south to north at a uniform speed (Mate, 1972).

Although a correlation between wintering population size and location of the hauling area is not apparent, the population peaks tend to decrease in size from south to north (Figure 10). Reductions in the size of population peaks probably represent animals which have stopped moving north to over-winter. Recognizable individuals were known to stay on one hauling area during the entire winter. The inferred progress of a migratory wave from the population peak data, was substantiated by the observation of identifiable animals during regular censusing. The time and location of sightings were recorded for each individual. Of 438 sea lions cataloged during the fall of 1969, 192 (44%) were seen at more than one hauling area. Of the 192 animals observed on at least two hauling areas, 183 (96%) were seen further north of where they were originally sighted, indicating that animals moved north when they moved at all. It is very doubtful that the sea lions cruised back and forth along the coast during the fall and winter. Thirty-one animals were

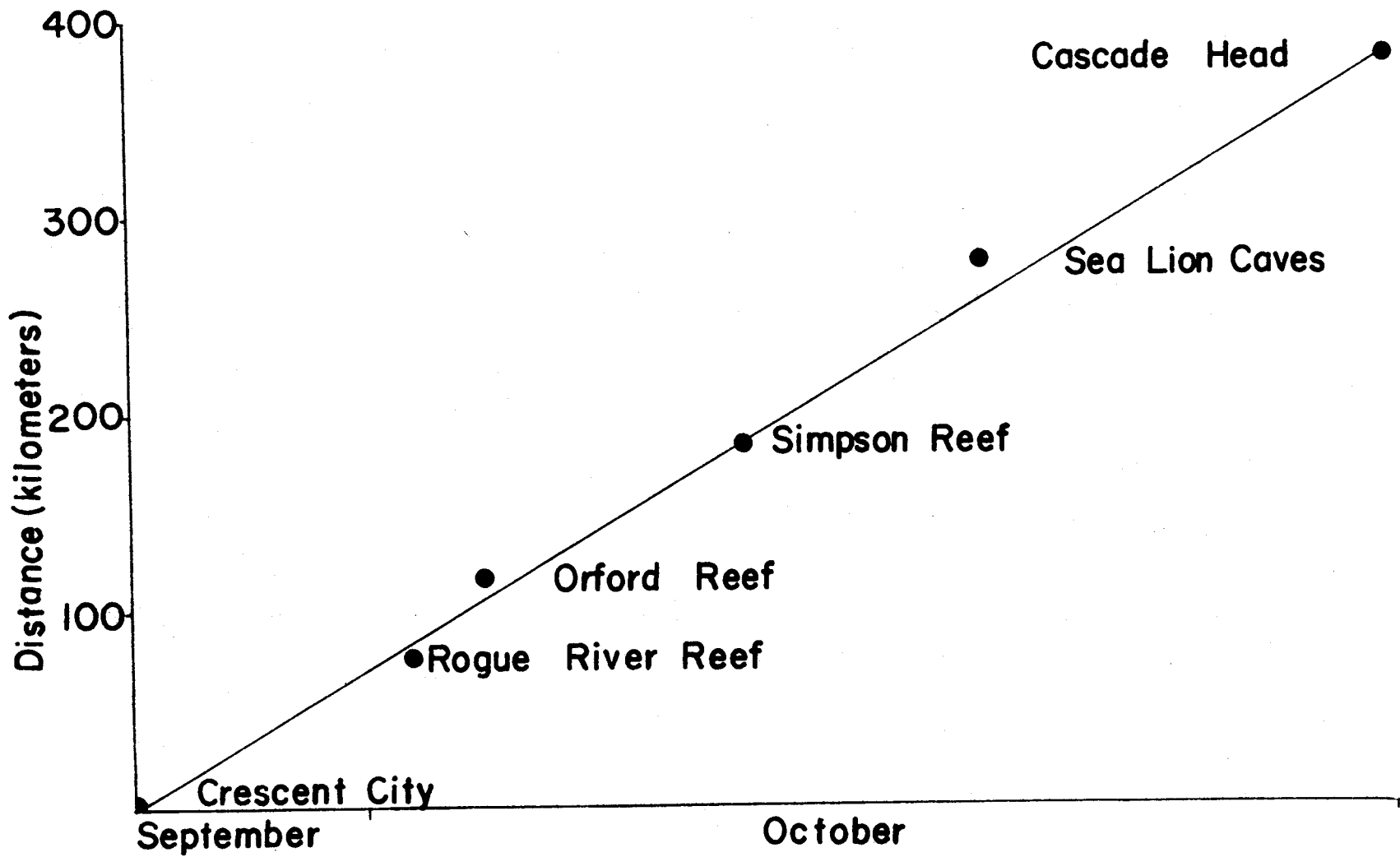


Figure 9. Timing of male Zalophus populations peaks.

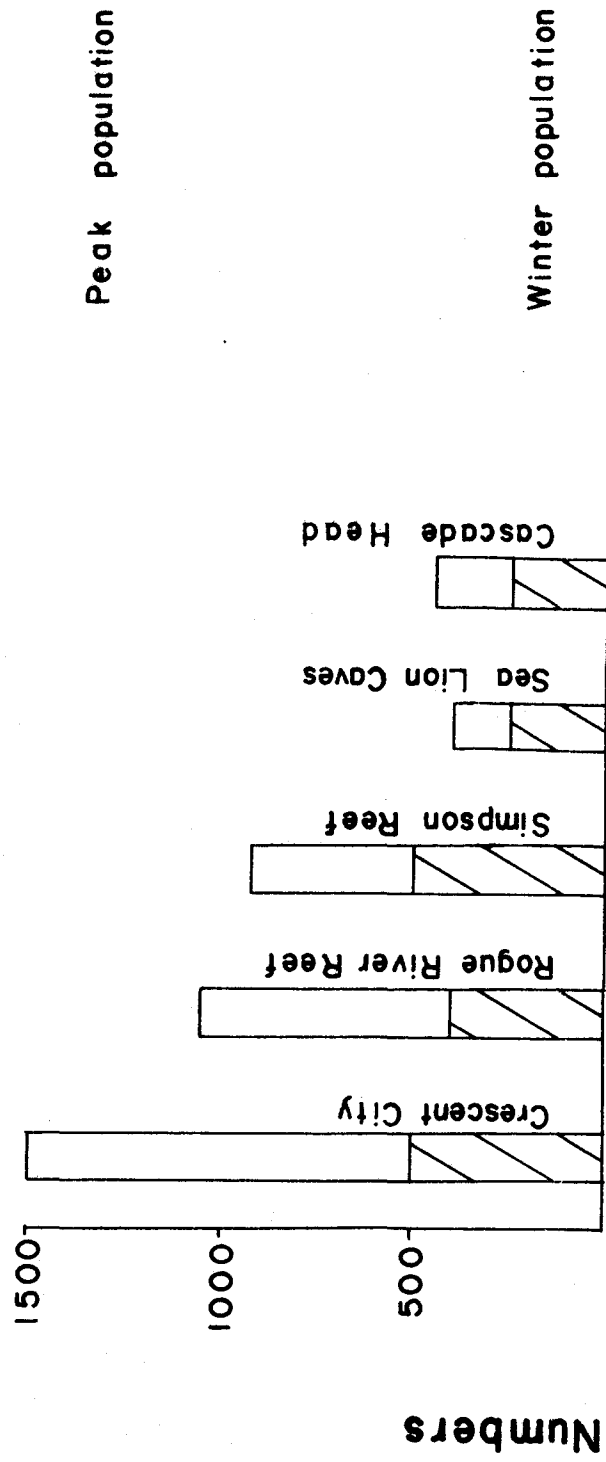


Figure 10. Size of peak Zalophus populations.

seen more than 12 times. An analysis of the data on these individuals indicates that sea lions hauled out and stayed 5 to 11 days on each hauling area as they moved north until arriving at their over-wintering location.

Information on the speed of individuals between hauling areas was extremely difficult to obtain. The duration of time between consecutive sightings divided into the distance between the points of observation yielded a conservative "speed." The fastest movement observed was over a distance of at least 61 kilometers between Orford Reef and Simpson Reef in an observed time of 34 hours. The distance actually covered may have been greater than 61 kilometers, and the time may possibly have been less than 34 hours if the animal left later than observed at Orford Reef or if its arrival at Simpson Reef was not immediately noticed. Sea lions are capable of short bursts of speeds from 19 to 24 kilometers per hour (King, 1964). "Burst" speed and "observed" speeds indicate that sea lions can move from one hauling area to another in much less time than is suggested by the data on population peaks.

Autumn Cohabitation

Both genera of sea lions exhibited post-breeding movements in 1968, 1969 and 1970. An influx of Eumetopias males of all ages arrived in Oregon during the second week in August (Figures 6-8). Male Zalophus also arrived at that time. Most of the data during this period was gathered at Simpson Reef and the following account will relate to that hauling area in particular, although the same general events were taking

place on other hauling areas. During the breeding season, the more contested and most reproductively active locations for Eumetopias were relatively flat areas which provided easy access to and from the water. Mild weather prevailed during the breeding period and some exposed areas were used that were unavailable to fall and winter residents because of wave action. During the fall, male Eumetopias competed for high elevations on the hauling grounds. Such males may have preferred these higher positions because they were not disturbed by animals entering and exiting from the water. Such locations were generally easier for the resident to defend because of the elevation. The defender would lunge his neck downward toward the challenger, who usually had poor "footing" in comparison with the resident. Very rarely was the holder of such a site displaced unless he was considerably smaller than the challenger. The sites were not permanent territories and were quickly occupied by another male when vacated. Cormorant Island, in the north cove of Cape Arago, is volcano shaped and protected from rough ocean conditions by Simpson Reef. As many as 350 sea lions have been observed here. The smallest individuals occupied the relatively broad, flat base of the island, while the largest males were near the top.

Conflicts between males for elevated sites were not as violent as those that occurred during the establishment of breeding territories, nor were they as common probably because of limited access to the area. The postures and vocalizations typical of conflicts were similar to stereotyped boundary displays observed during territory maintenance but occurred less frequently between adjacent males. This difference

may have been due to the extreme vertical relief between neighbors as opposed to the generally flat nature of most rookeries. The importance of vertical barriers and their influence on reducing boundary displays during the breeding season has been pointed out by Gentry (1970). Animals next to one another at the same elevation acted much like animals close together on any horizontal hauling area; a male in a higher position than his neighbor was definitely dominant. Cormorant Island was strictly a hauling area and in August was inhabited exclusively by Eumetopias. Eumetopias that bred at Simpson Reef rarely hauled out on Cormorant Island during the non-breeding season.

As Zalophus moved into the area, they occupied the islands behind Simpson Reef in a specific order. Zalophus did not participate in the vertical hierarchy of Eumetopias nor in one of their own. Zalophus commonly left elevated places, when Eumetopias males approached. These behavioral differences may be related to the difference in breeding site preference for these two species. Eumetopias most commonly breed on rocks, whereas Zalophus often breed on sandy beaches close to the water (Peterson and Bartholomew, 1967). As a result, Zalophus may not be as experienced as Eumetopias with vertical cues as a sign of territory boundaries. Individuals of both genera appeared to avoid each other during the early portion of their cohabitation which was marked by separation of the two populations. When both species occupied the beach east of Shell Island, species specific groups remained separated. As the numbers of Zalophus increased, this "clumping" behavior deteriorated. In late August, when the two populations were at parity, mingling of Zalophus among Eumetopias was common. The continued increase of

Zalophus corresponded to the departure of Eumetopias from the hauling area. The numbers of Eumetopias did not decrease until outnumbered by Zalophus (Figures 6-8). Although typical "jousting" and mock-battles occurred among Eumetopias or Zalophus, interspecific interactions were limited to Eumetopias chasing Zalophus off elevated hauling sites. The rather dramatic reduction in the number of Eumetopias and the peculiar clumping behavior suggested an avoidance behavior by Eumetopias in response to an increased number of Zalophus. However, similar movements are not seen at Año Nuevo Island, California, where Zalophus do not arrive in large numbers until after adult male Eumetopias have left the island. In Oregon, the consistent pattern of an increased number of Eumetopias followed by an increased number of Zalophus occurred just prior to the movement of Eumetopias away from such areas. This movement by Eumetopias produced a reduced secondary migratory wave phenomenon at some hauling areas similar to that previously described for the peak population of migratory male Zalophus.

The migratory wave of Eumetopias was different in many respects. The initial increase in the number of subadult and adult male Eumetopias during early August appeared at many of the hauling areas at approximately the same time. Secondary increases in Eumetopias populations corresponded with the mass exodus of Eumetopias from hauling areas further south, where they appeared to be "displaced" by Zalophus as previously described. The number of animals in such a secondary wave was never equal to more than 40 percent of the individuals observed leaving hauling areas immediately to the south. It is likely that most of the

Eumetopias "displaced" by Zalophus moved quite a distance to the north before finding a hauling area for the winter. No sizable winter hauling areas for male Eumetopias exist south of Puget Sound, Washington. A notable exception was the Sea Lion Caves area where some males stayed farther into the fall. At this location, Eumetopias and Zalophus have basically separate hauling areas. Although both species were occasionally found in the same place, Zalophus never outnumbered Eumetopias in the cave. Zalophus hauled out mainly in a cove north of Sea Lion Caves. Small numbers of Eumetopias occasionally hauled out in the cove with Zalophus during periods of rough weather or crowded conditions in the cave. The north cove was not used by adult male Eumetopias during the breeding season, but was occasionally used by a few subadults during the summer. All Eumetopias over-wintering at Sea Lion Caves were females or subadults. No pups have been observed to over-winter in the area although some yearlings were seen there during the spring and will be discussed later (page 51). Some females and pups over-wintered at other hauling areas along the Oregon coast (Orford Reef and Rogue River Reef) but were fewer in number than during the breeding season.

After the Eumetopias males had left Simpson Reef, the Zalophus population continued to rise until reaching a peak in early October (at Simpson Reef, Figures 6-8). As mentioned before, the Zalophus population then declined sharply, stabilized, and the number of Zalophus decreased gradually throughout the rest of the winter. Individual Zalophus were known to stay at a particular hauling area from the time the peak arrived until mid-spring. Twelve individuals were known to

arrive at Simpson Reef during 1969 within 5 days to the year of their time of arrival in 1968. One of these sea lions was a mature male of medium size and appeared to be totally blind. In both years, I approached to within 1 meter of the animal without detection. When touched, the animal barked rapidly toward a nearby rock wall (about 1 meter away) and moved quickly along the wall toward the water, suggesting an airborne echo-location ability.

Cohabitation during 1970 was marked by an unusual lethargy among almost all Zalophus. Individual Zalophus were found in atypical locations, often associated with fresh water. Clinical and behavioral data suggest that the illness is leptospirosis (Vedros et al., 1971). The diagnosis, along with various laboratory and field observations, is discussed in Appendix II (page 75). It is sufficient here to say that the illness affected 90 percent of the Zalophus observed along the Oregon coast. Those seemingly unaffected were the largest and perhaps the oldest male Zalophus present. At least 10 percent of the population in Oregon died as a result of this disease, which along with the unusual movements of individual Zalophus may explain why the numbers of Zalophus over-wintering were lower than in 1968 and 1969.

Spring Cohabitation

At the beginning of this chronological account, brief mention was made of the spring fluctuations of Eumetopias just before their breeding season. Further details on Eumetopias and Zalophus during this period will now be given. The predominant winter resident in Oregon was

Zalophus (except during 1971, page 52). The numbers of Zalophus dropped gradually between November and March, either because of further northward movements or of inclement weather which kept the animals offshore. All Zalophus had left Oregon by the second week of June. A period of spring cohabitation began when Eumetopias males started to appear in late March. A transitory population of adult male Eumetopias appeared to move south rapidly in late April and early May (Figures 6-8).

A migratory wave of female Eumetopias was observed along the Oregon coast moving from north to south during March and April (Figure 5). Between 40 and 60 percent of these females were still suckling their pups from the previous year. The low incidence of females with yearlings during the breeding season (4% at Año Nuevo Island, California according to Gentry, 1970; and a maximum of 12% at Oregon rookeries [Mate, unpublished data]) suggests that many yearlings had been weaned or had died during this time. The only yearlings observed by Gentry (1970) at Año Nuevo were nursing. Sandegren (pers. comm.) has observed that 81 percent of the females on the rookery that he studied in Alaska were accompanied by nursing subadults. The nursing periods of Eumetopias may vary, being relatively long for northern populations (the pups there may require more nourishment) and becoming progressively shorter to the south where animals are likely weaned in the spring. A detailed discussion of pup mortalities is presented elsewhere (see Appendix I, page 69).

Seasonal Fluctuations in 1971

The arrival of Eumetopias during the spring of 1971 and the subsequent breeding activities were the same as those described for 1968, 1969 and 1970. At the end of the breeding season, an influx of sub-adult and adult males occurred in late August as before. The first male Zalophus was also seen at about the same time. The numbers of Zalophus in the migratory wave, which usually followed the increase of Eumetopias, was considerably reduced. Population peaks at individual rookeries were from 70 to 85 percent lower than during the previous 2 years. Similar, but less drastic reductions in the fall Zalophus population were noted at Año Nuevo Island (LeBoeuf, per. comm.). Figure 11 illustrates the fall population of Zalophus during 1971 at Simpson Reef and can be compared with data taken the previous three years (Figures 6-8). The timing of peak population numbers was very similar to that observed before. The cohabitation of Eumetopias and Zalophus was different during 1971 and might have been due to the drastically reduced number of Zalophus present. Clumping of Eumetopias was noticeable during August and the first two weeks of September. By mid-September, both species were intermingling as was usually the case by the end of August. Male Eumetopias did not depart en masse from hauling areas shared with Zalophus in early September as they did during the previous 3 years, but instead left gradually during late September and early October. A greater number of female Eumetopias over-wintered on traditional hauling sites in Oregon during 1971. These females integrated well with Zalophus males and the only interspecific conflicts observed

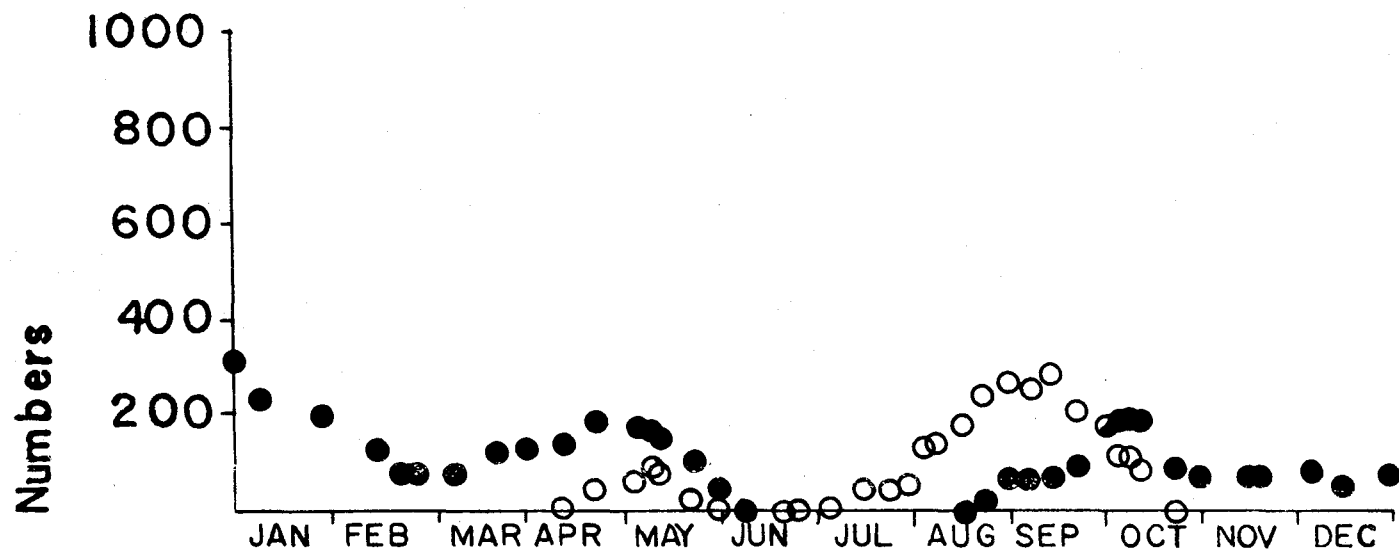


Figure 11. Male Eumetopias (○) and male Zalophus (●) at Simpson Reef during 1971.

were when a female "protected" her pup.

The drastically reduced numbers of Zalophus during the fall of 1971 may have been due to one or a combination of the following possibilities: (1) The northward migration into Oregon was greatly reduced in 1971 for some reason(s) (presumably related to the 1970 illness). (2) A much greater mortality than was observed occurred during 1970-71 among those animals which move as far north as Oregon. (3) The uniformity of data taken during the previous 3 years was a matter of chance.

The probability of such consistency being coincidental seems quite low. The first alternative may necessitate crediting these highly intelligent animals with reasoning powers (association of illness with northward movement and a subsequent avoidance of such behavior) or they may have stayed south for some other reason. The second alternative, which seems most credible, implies that the 1970 illness produced a mortality of 75 percent among migrant Zalophus males in Oregon. Although leptospirosis is probably the most common wildlife and domestic disease among mammals, there are no records of mortality caused by leptospirosis exceeding 15 percent in any species. The difference in marine mammal kidney function and their salt water environment may be factors in causing increased mortality.

The exact age distribution of the animals seen during 1971 is not known; however, the individuals observed definitely represented predominantly older age classes. Very few subadults were seen. All males had well developed sagittal crests and were larger than the average

Zalophus males observed in prior years. As mentioned before, older animals during 1970 seldom exhibited any symptoms of sickness. If these older animals either did not contract the disease or had a lower mortality rate than other age classes, it is not surprising that they represented a greater portion of the population in 1971 than in 1970.

Summary of Seasonal Fluctuations of Zalophus

The breeding range of Zalophus extends from Mazatlán, Mexico ($23^{\circ} 14'N$) northward to San Miguel Island, California ($34^{\circ} 03'N$). Peterson and Bartholomew (1967) conducted an intensive investigation of the general biology of this species during the summer of 1965 at San Nicholas Island ($33^{\circ} 14'N$). The number of territorial bulls dropped 86 percent by 2 August, from the breeding season high of early June. A significant decrease was also observed among non-breeders (subadult males and females) while the breeding adult female population and pups (to a lesser extent) showed an increase during the late summer. Bartholomew and Boolootian (1960) have noted that the winter Zalophus population at San Nicholas is larger than the summer population, and Odell (1972b) has observed that this winter population peak consists of females and pups predominantly. Increased numbers of male Zalophus during the winter in southern California were first recognized by Fry (1939). Bartholomew and Hubbs (1952) observed that almost no adult males are found during the winter on the San Benito Islands ($28^{\circ}N$). It is therefore unlikely that territorial bulls leaving areas such as San Nicholas head south.

Small numbers of non-breeding Zalophus can be found north of the breeding range as far as Crescent City, California (41° 46'N) during the breeding season. The population of male Zalophus at Año Nuevo Island, California (37°N) fluctuates seasonally (Orr and Poulter, 1965). Zalophus start to arrive at the island in mid-July, toward the end of their breeding season and reach a peak about the first of September (Orr and Poulter, 1965). More recent observations have been made on Año Nuevo by censusing every Sunday morning, regardless of the weather and of recent disturbances of the hauling areas (Lance and Peterson, 1968). The failures of this type of censusing have been discussed. The data revealed a broad autumn peak in the Zalophus population during August, September and October, but a distinct peak could not be discerned. Both studies found that the wintering population of Zalophus on Año Nuevo Island is less than one half of the population observed during the autumn peak.

Population peaks occurred at hauling grounds within my study area (Crescent City, California, north to Astoria, Oregon) between the second week in September and the end of October. The timing of the population peaks is shown in Figure 9. These population peaks were consistent in size and timing for individual hauling grounds during 1968, 1969, and 1970. Fewer numbers of Zalophus were seen during 1971, although the timing and sequence of population peaks at the various areas were similar to those observed the previous three years. Individual Zalophus did not arrive in Oregon until early August in the south or until mid-August in the north. The arrival of individual Zalophus and

the subsequent population peak occurs later and later at hauling areas farther to the north. The hypothesis, first suggested by Fry (1939) and more recently elaborated by Bartholomew (1967), that males of this species participate in a northward migration following the breeding season is confirmed. Observations of individual male Zalophus indicate that these animals move northward during the fall, stopping at each hauling area for varying lengths of time. The population peaks diminish in size from south to north, presumably representing animals dropping out of the migratory wave to over-winter at various locations along the coast.

The data available from other studies pose some difficulties in interpretation (Figure 12). The time of male Zalophus departure seems to be well established from the work of Peterson and Bartholomew (1967) and Odell (1972b). The beginning of population build ups (indicated by the solid line) at Año Nuevo Island, California appears to start at the "proper" time, although the peak population (the filled oval) is not reached until much later than predicted from the Oregon data. This may be the result of animals leaving the breeding areas to the south and largely by-passing Año Nuevo, or more likely staying offshore at this time to feed after the rigors of the breeding season. It is also possible that the movement is not discrete at this time and animals arrive at Año Nuevo and leave quickly in small groups without a resultant build up. Little is known about the timing or numbers of animals from Año Nuevo to Crescent City except that hauling areas do exist and are well populated seasonally. The occurrence of Zalophus at the northern extent

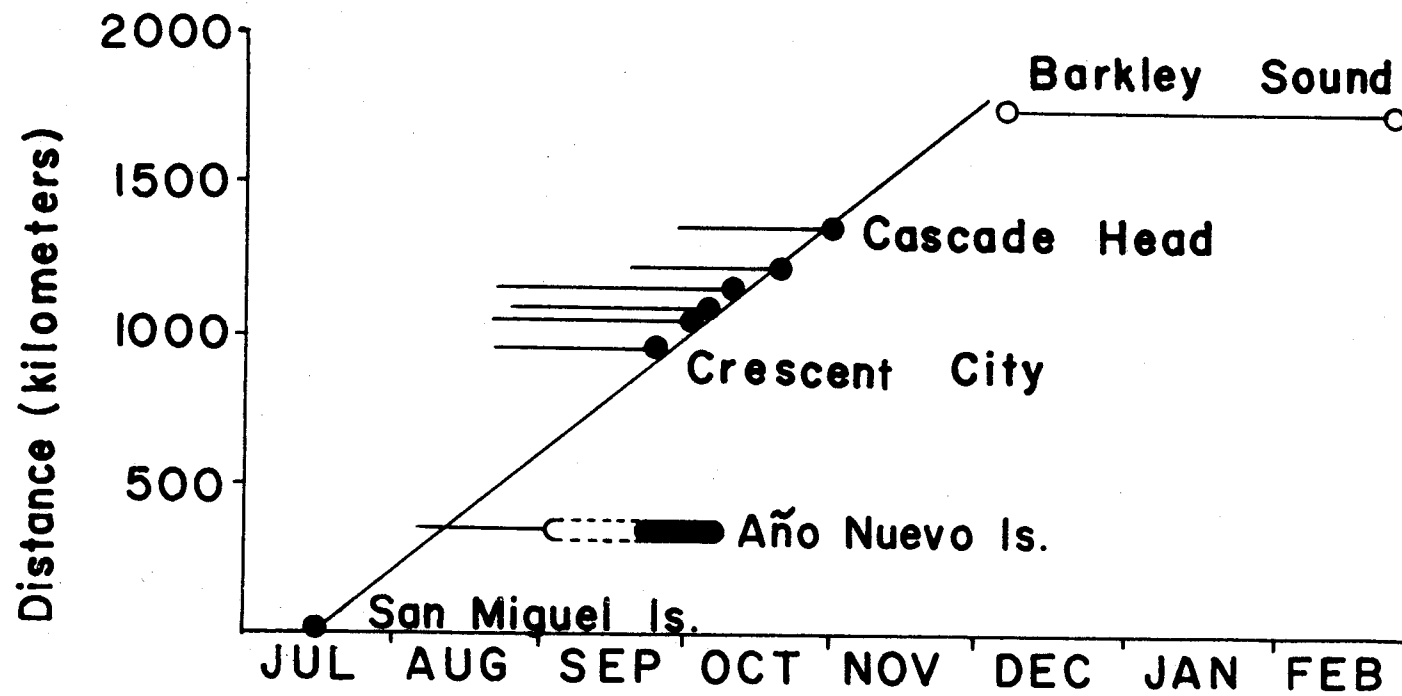


Figure 12. The increase and peak of Zalophus populations along North America.

of its known range has been recently documented by Bigg (in press) and is open to interpretation at this stage. Of 4 censuses in the Barkley Sound area of B.C., 3 revealed the presence of Zalophus (the solid line between the open circles of Figure 11). The maximum observed population was the last census, numbering almost 500 animals. A prediction of the total number of animals moving north of Oregon from the diminishing peak data (Figure 10) indicates that probably up to 1000 Zalophus move north of Oregon. Censusing of the Washington coast has not been done regularly and only two areas (of historically small importance to Eumetopias), exist. It therefore may be that the peak passed through Barkley Sound at the predicted time but was not censused and that the first sighting of animals represents the winter resident population. If this is true, the maximum population observed in late February may represent the organization of a southward moving migratory wave as males start to head south for the breeding season. Alternatively, an autumn population peak for male Zalophus may not exist in British Columbia if the wave phenomenon observed along the Oregon coast degenerates. If such is the case, the high February count may be the result of individual Zalophus slowly moving northward during the winter. This would explain the mid-winter decline observed in Oregon during this study and at Año Nuevo Island by Orr and Poulter (1965) and Lance and Peterson (1968). An interesting mid-winter peak in the population of female Zalophus at San Miguel Island has been noted by Odell (1972b, in press), but the origin of these females is not yet known.

Spring population peaks for Zalophus were observed at several

hauling areas, but a wave phenomenon was not pronounced. Most of the spring population peaks were simultaneous during late April or early May. The spring peaks were only 30 percent as large as the autumn peaks and individual animals were not known to go from hauling area to hauling area during this time. Spring population peaks for Zalophus have been noted in California at Año Nuevo Island (Orr and Poulter, 1965) and at Point Reyes, Bird Rock, and the Monterey Breakwater (Lance and Peterson, 1968). Zalophus were not found in Oregon between mid-June and mid-August.

All but the largest Zalophus males showed symptoms of an illness during the fall and winter of 1970. The morbidity was estimated at 90 percent while a conservative mortality estimate of 10 percent was made from direct observation of dead animals found on Oregon beaches. The distribution of live animals during that time was generally the same as other years observed, except that individuals were frequently in atypical locations, often associated with fresh water.

During the fall of 1971, reduced numbers of Zalophus may have been due to one or more of the following:

- (1) atypical movements perhaps related to the occurrence of an illness during 1970,
- (2) high mortality among the animals sick in 1970,
- (3) normal fluctuation patterns (the similarity of the data from 1968, 1969, and 1970 was coincidental).

Summary of Seasonal Fluctuations of Eumetopias

Eumetopias bred in Oregon on rookeries during June and July. The peak of pupping took place during the first week in June. The mating season was over by the middle of July, at which time breeding males gave up their territorial maintenance and left the rookery areas. A post-breeding influx of subadult and adult males moved to hauling areas, many of which were close to rookeries. Some of the adult males in this category were known to have bred at rookeries farther to the south. No adult Eumetopias males could be found south of Oregon after August. The population peak of Eumetopias at each rookery took place at nearly the same time each year. An increase in the number of Eumetopias at northern hauling areas appeared to be the result of Eumetopias which had left more southern hauling grounds after the arrival of large numbers of Zalophus. The en masse movement of adult male Eumetopias from a hauling ground coincided with a shift in numerical-dominance from Eumetopias to Zalophus. All adult male Eumetopias had left Oregon by mid-September during 1968, 1969 and 1970. Female Eumetopias increased slightly during the fall, as did the pup population. Some females and pups were known to move north within Oregon and the presence of occasional pups with tags from California indicated an even greater range of this northward movement. Female populations decreased during the winter and females intermingled with Zalophus except at Sea Lion Caves where the two species remained fairly separate. A spring migratory wave of female Eumetopias (many in the company of a yearling) was seen slowly moving southward during March and April. It would appear that the winter

depression in the female population may have been the result of some of these animals moving farther north. While the northward movements were not well documented, the southern movement during the spring was quite evident. Individual females were known to drop out of this movement to breed in Oregon.

Eumetopias bulls were seen infrequently by late March; many large males occupied hauling areas during mid-April and early May, staying for only a day or two. Males established territories in Oregon by the middle of May. Very few males were observed at more than one area during the spring. The later arrival of males in California implies a southward movement for this group also.

The pattern of seasonal movement of male Eumetopias was generally similar to the movements hypothesized by Fry (1939) for Zalophus. Some females and pups were known to move north during the fall (and probably during the winter), while females in the company of yearlings were seen moving south during the spring prior to the breeding season. Therefore, the movements of female Eumetopias did not parallel the southward winter movements hypothesized for female Eumetopias by Bartholomew (1967). Movements of female Zalophus may be similar to those of female Eumetopias. The data reported by Peterson and Bartholomew (1967) and by Odell (1972b) indicate a post-breeding increase in the numbers of pups and breeding females at San Nicholas Island, a northern rookery in the Zalophus breeding range. There are no data to support the hypothesis that these animals moved to San Nicholas Island from the north or from the south.

During the fall of 1971, the migratory male Zalophus population was very reduced (as compared with the previous 3 years). Instead of Eumetopias males moving en masse from the hauling areas in early September, the population gradually declined during late September and early October. A greater number of Eumetopias females over-wintered in Oregon during 1971 than was the case in 1969 or 1970. Both the actions of the male and female Eumetopias populations are considered supportive of a hypothesis that Eumetopias migratory movements are modulated by some form of population pressure exerted by Zalophus.

It is singularly amazing that the small populations of Eumetopias which breed in the southern extent of this species' range along the California and Oregon coasts have survived for such a long time. It is not known what the populations along this coast looked like before the white man came, but reports, such as those of Scammon (1874) describing the slaughter of thousands of sea lions for their oil, attest to the hunting pressure applied to these species as recently as one century ago. More recently, Fry (1939) discussed the harvest of sea lions in Lower California (probably Zalophus) for use in dog food. Bounties were paid on seals and sea lions in Oregon during the early part of this century and accounted for seemingly large numbers of animals in comparison to today's populations. During 1925 alone, 1387 sea lions were turned in for bounty (Pearson and Verts, 1970). What would have been the long range population effects of such annual harvests along this coast had they continued? It is certainly hard to say. It does seem reasonable, judging from the number of animals turned in for bounty

during individual years, that the sea lion populations along the Oregon coast have been reduced substantially during this century. The populations presently on Oregon rookeries may, in fact, be a small percentage of the number of animals which once inhabited these areas.

Año Nuevo Island, California, has supported a stable breeding population of between 1,500 and 2,000 Eumetopias for the last 50 years (Evermann, 1921; Rowley, 1929; Ripley et al., 1962; Orr and Poulter, 1965; Gentry, 1970). However the southern extreme of the breeding range has changed substantially since the turn of the century. Bartholomew (1967:241) has summarized the decline of Eumetopias in the California Channel Islands as follows:

When records of the pinniped population of the California Islands were first begun in the late 20's, the Steller sea lion was the most abundant pinniped in the southern California group. Its population peaked at a little more than 2,000 in the late 1930's and has been declining during the 30 subsequent years. In 1958 the total breeding population of this species in the Southern California Islands had fallen to less than 100 and was confined to a single rookery on the western tip of San Miguel.

During the last two breeding seasons, the "rookery" at San Miguel has been occupied by a single adult Eumetopias and by some Zalophus females. It therefore seems that the southern extent of the Eumetopias breeding range is slowly moving northward. This reduction in the numbers of Eumetopias in the southern part of its range may be the result of:

- (1) A physiological threshold to some environmental factor (e.g. an increased concentration of contaminants in food sources which might lower the reproductive potential of these rookeries).
- (2) A physical factor, such as water temperature (Bartholomew, 1967), which has been

shown to increase during the period from 1955 to 1967 and may affect the distribution of various food species. (3) A population pressure exerted by Zalophus in the form of niche competition.

That the breeding and non-breeding ranges of male Zalophus and male Eumetopias do not overlap is now an established fact. This study has shown that the presence of Zalophus in large numbers has apparently produced modulations in the movements of Eumetopias males during their post-breeding movements (resulting in Eumetopias leaving areas sooner than when Zalophus are not present in great numbers). The enormous growth of the Zalophus populations in the Channel Islands has been discussed by Bartholomew (1967) and Odell (1971) and may now have leveled off after an exponential growth phase of almost 40 years. It seems likely that the cause of apparently Zalophus-induced modulations of the male Eumetopias post-breeding movements and the cause of a northward expanding Zalophus breeding range (and northward shrinking Eumetopias breeding range) may be the same. These two species occupy such a similar niche, it may be difficult to determine the critical resource(s), for which they compete (food, rookery locations or other unknown limiting factors).

The basic questions still exists: why do these animals migrate? How has migratory behavior developed through evolutionary time? Has it been closely associated with sexual dimorphism? predator-prey relationships? Have the causitive agents long since disappeared, but having had such selective value in the distant past, now established this behavior genetically to be carried from generation to generation? It is entirely

possible that from our necessarily short-term view of marine mammal populations, that we are unable to see the "big picture." We may, in fact, be observing and quantifying relic behaviors, which have no adaptive value in the present biology of these species.

APPENDIX I

POPULATION DYNAMICS OF EUMETOPIAS ON OREGON ROOKERIES

Population dynamics is the totality of changes that take place during the life of a population (Hanson, 1962). In the limited sense of the original definition of "population," interacting animals of the same species in a common spatial arrangement, I will discuss the major factors in recruitment at Eumetopias rookeries in Oregon (births) and briefly discuss the factors influencing mortality rates in the various age classes.

Birth Rate and Pup Mortality

The birth rate for each rookery was derived from the highest pup count divided by the maximum population observed at each location during the breeding season. A more meaningful statistic, because of the polygamous nature of sea lions, is the number of successful births per sexually mature female. The highest pup count was less than the actual number of pups born (as some may have been born before the count and died while others may have been born after the count was made). The population is probably close to the actual number, although some females may have been off the rocks during the highest census. Data on adults, non-breeders (subadults) and pups at the two most thoroughly studied

rookeries, Orford Reef and Simpson Reef, are shown in Table 4. The birth rate was consistently lower at Orford Reef, as was the male to female ratio. The birth rate may be high and the male to female ratio may be low if females with young spend only 63 percent of their time on shore as they are reported to do at Año Nuevo Island (Gentry, 1970). A greater portion of the females at Orford Reef were of small size and the possibility that many of these were just entering their first breeding season or were still immature, makes calculation of fecundity quite difficult. The birth rate at Simpson Reef is probably higher than at Orford Reef because very few young females and no bachelor bulls were

TABLE 4. Reproduction data for a large and a small Eumetopias rookery in Oregon.

	1969	1970	1971
Orford Reef			
Territorial bulls	93	104	95
Breeding adult females	550	675	750
Non-breeders	200	250	200
Total adults	843	1029	1045
Pups	413	296	365
Birth rate	.49	.29	.35
Pups/adult female	.75	.44	.49
Male/female (adult)	1:5.6	1:6.5	1:8
Simpson Reef			
Territorial bulls	4	4	3
Breeding adult females	36	65	46
Non-breeders	0	0	0
Total adults	40	69	49
Pups	28	39 (51)	29
Birth rate	.70	.57 (.74)	.59
Pups/adult female	.78	.60 (.81)	.63
Male/female (adult)	1:10	1:17.3	1:16.3

observed during the peak of the breeding season. Note that there is very little difference between the two rookeries for pups/adult female.

The low variability in the number of territorial bulls at both locations suggests that territories may conform to certain minimum size requirements or may consistently be established along topographical boundaries which limit the number of possible territories. The territorial boundaries at Simpson Reef during 1969 and 1970 were almost identical: in this instance, it may have been more important that at least two of the four males breeding at this location each year were the same.

The apparent low birth rate at both rookeries during 1970 and 1971 was probably the result of bad weather during late June. Careful observations at Simpson Reef during 1970 revealed a minimum of 51 pups born during the entire breeding season, corresponding to a birth rate of 74 percent. The difference between this figure and the birth rate derived from the maximum pup census is due to premature births and post-census pupping. The method of dividing pup counts by the total population is clearly inadequate to assess birth rate information. The time of censusing is critical in this regard. Table 5 compares the highest pup counts of both Orford Reef and Simpson Reef with pup counts taken during early August and shows a calculated pup mortality on the basis of these counts. The August figures are considerably lower than those of June or July. While pups have usually learned to swim by August, none were observed to go far from the rookery area. The August counts are believed to include most, if not all, of the pups in each area. Sandegren (1970)

TABLE 5. Calculated pup mortality for a large and a small Eumetopias rookery in Oregon.

		Highest census pupping season	Early August census	Calculated mortality rate
Orford Reef	1969	413	324	22%
	1970	296	188	36%
	1971	365	236	35%
Simpson Reef	1969	28	16	43%
	1970	39 (51)	9	77% (82%)
	1971	29	5	83%

observed a similar reluctance on the part of pups to leave the rookery area until at least 36 days old and then only in the presence of their mothers. Assuming that all pups were counted in both surveys and that pups were not yet able to swim away from the rookery area in August, it would appear that considerable mortality among pups occurs during the first two months after birth. The higher mortality rate calculated for both rookeries during 1970 and 1971 may have been the result of rough swells and early summer storms those years. The apparently higher pup mortality rate at Simpson Reef was probably due to the relatively exposed nature of this small area. While pups at Orford Reef could move to higher elevations during rough weather, the entire rookery at Simpson Reef was observed completely awash on numerous occasions during the course of this study. Many investigators have observed that much pup mortality is caused by drowning. Sandegren (1970) gives a detailed account of the development of swimming skills in Eumetopias pups. The lack of adequate fat, which insulates against the cold, may cause pups which are swept off the rocks, to die of exposure. A physiological

difficulty encountered by sea lion pups when swimming is a reduced concentration of myoglobin, which is responsible for oxygen storage in the muscles (Lenfant et al., 1970). Oxygen reserves are probably depleted quickly during strenuous activity, possibly limiting the ability of pups to reach shore.

Another influence upon recruitment in sea lion populations is the number of stillbirths and premature births. Sandegren (1970) reported seeing no stillbirths for Eumetopias in Alaska. However, his observations did not begin until mid-May and most of the stillbirths that I observed in Oregon were prior to May. Peterson and Gentry (cited by Sandegren, 1970) have observed stillbirths among Eumetopias quite commonly at Año Nuevo Island. Stillbirths in Oregon occurred as early as the first of March and accounted for approximately 1 out of every 100 births. The first live, premature young were born during the first week of April but did not live long. The first pups that appeared to survive were born in early May. Premature births (arbitrarily defined as births before May, including stillborns) represented about 4 percent of all births. This is less than the 8 percent observed by Odell for Zalophus during 1970.

During the breeding seasons, the calculated pup mortality ranged from 22 percent to 83 percent and appeared to be related to the weather. These figures are much greater than the 4 percent observed by Bartholomew and Peterson (1967) for a Zalophus rookery at San Nicholas Island. Zalophus may have considerably lower mortality rates because their more tropical distribution places them in less risk of encountering summer

storms. In the event of rough weather, Zalophus pups may be less likely to be swept away because they are located on sandy beaches and can simply move farther up on the beach. Eumetopias pups in Oregon have difficulty in rough water returning to the rookery even if they are good swimmers because of the vertical nature of some of these areas. The mortality rate for Eumetopias pups is also greater than the 5 to 16 percent observed for Callorhinus pups during the breeding season (Marine Mammal Biological Laboratory, 1969). Sandegren (1970) observed a pup mortality of 12.5 to 14 percent during the first two weeks after birth for Eumetopias in Alaska. Thorsteinsen and Lensink (1962) also estimated pup mortality for Eumetopias in Alaska and determined it to be approximately 10 percent. Pup mortality of Eumetopias in British Columbia has been described as "low" (Pike and Maxwell, 1958). Various estimates of pup mortality for Eumetopias have been made for the population breeding at Año Nuevo Island. Evermann (1921) counted more dead and dying pups than live ones during a visit to Año Nuevo Island on 27 June, 1920. The cause was attributed to a storm during mid-June. Orr and Poulter (1967) estimated the mortality of pups at Año Nuevo as "high." Gentry's (1970) impression was that the pup mortality at this area was below 10 percent during the course of his study.

Subadult and Adult Mortality

It was impossible to determine the cause of death of almost 50 percent of the dead sea lions found along the beach because they were extensively decomposed. Until 1971, the major identifiable cause of

subadult and adult deaths in Oregon was gun shot wounds. After these mammals were declared non-game species in 1971, beach cast animals were less frequent. Excluding all obvious gun shot wounded animals, the observed mortality of subadults was less than 2 percent for 1969, 1970, and 1971. Dead adult females were never found. Adult males dying from other than gun shot wounds accounted for approximately 2 percent of the adult male population during the breeding season (May through July). Adult male deaths from August through October accounted for another 1 percent, based on an estimated 400 adult males which move through the state during that period.

Only one subadult death was directly attributable to intraspecific conflict. A four-year-old male received serious injuries from territorial males at Simpson Reef during 1968. The animal ventured onto the rookery and was confronted immediately by a large territorial bull, which cut off the subadult's retreat to the water. The young animal backed away from one territorial bull only to enter the territory of another. Two small wounds on the neck and shoulder of the subadult were inflicted by the territorial males. The juvenile appeared frightened and in his haste to escape backed up into a third bull which either physically tossed the young animal or caused him to lose his balance and perform a spectacular somersault over a particularly steep part of the rocky reef. The animal appeared stunned at first, but soon swam away slowly. Observed at short range within an hour of the conflict, a straight gash across the animal's flanks 13 inches in length was still bleeding freely. The animal was found dead the following day.

and collected as a specimen.

Observations of interspecific conflicts were few. Only one death from such an encounter was observed. Four large killer whales, Orcinus orca, scared most of the sea lions and seals out of the water at Simpson Reef, before the whales were ever visible to me. The four whales as a group entrapped a medium-sized subadult Eumetopias by circling around it. One whale was observed to eat the entire sea lion.

APPENDIX II

FIELD AND LABORATORY DATA ON A WIDESPREAD ILLNESS AMONG ZALOPHUS

The progression of the Eumetopias breeding season in 1970 was similar to that for the years 1968 and 1969. When the breeding season ended, Zalophus began arriving at the same time as during the previous 2 years. On 23 September, an adult male Zalophus was sighted in Kentuck Inlet, which empties into Coos Bay, almost 3 kilometers past a tide gate. This location is a distance of at least 8 kilometers from the mouth of the bay and is the first fresh water tributary entering the bay. A sea lion this far from the ocean was very unusual and the first observations of its kind made during the study. Although harbor seals commonly ascend rivers, reports of sea lions entering fresh water systems are rare. Weed (1936) reported the capture of a sea lion (presumably Eumetopias) in a pasture near Oregon City, Oregon, a distance of over 150 km. from the ocean. The Zalophus found in Kentuck Inlet was lethargic, was easily approached, and was observed to drink water regularly; these behaviors are unusual for the species. As mentioned before with regard to breeding male Eumetopias, some investigators suspect that sea lions obtain their water as a metabolic byproduct of the fish they eat. Animals have never before been observed drinking salt water or fresh water. The next day, 24 September, two Zalophus had

passed the tide gate at Kentuck Inlet and both exhibited the lethargy and thirst noted the day before. A kidney disorder was suspected because of the extreme and abnormal thirst.

The severity of the problem was revealed in reports to the Oregon Institute of Marine Biology from private citizens and employees of the Oregon State Fish and Game Commissions. The overall movements of the migratory wave of male Zalophus were very similar to those observed during 1968 and 1969. The timing of peak populations at individual hauling areas, total number of individuals present, and their distribution along the coast were almost identical to the previous two years. However, from Los Angeles California to Astoria, Oregon male Zalophus were reported ashore in unusual locations and were remarkably tolerant of humans. Reports apparently started coming in around the San Francisco Bay area shortly before similar observations were made in Oregon.

Most of the reports in California were received by Mrs. J. Schonewald of the California Academy of Sciences. By 12 November, 239 "cases" had been reported to the Academy from Fort Bragg southward to Carmel Bay. No regular censusing of these areas was conducted, and there was probably some duplication of reports. During the same time period, 83 carcasses were reported for that area. Seven animals were captured and died shortly thereafter and 35 were killed. By 23 November, data for the same vicinity totaled 284 cases and 116 beach carcasses. It was not known whether the increase in the number of reports was due to an increased public awareness resulting in more reports or an increase

in the actual number of cases occurring.

In Oregon, data taken by other observers and myself were kept separate. An attempt was made to confirm reports received from all observers. Beaches were surveyed from a four-wheel drive vehicle as regularly as the weather would permit. Dead animals were marked with yellow, florescent paint to prevent recounting. Physical descriptions of all such animals were taken along with a canine tooth whenever possible. By 17 November, I had found 64 beached carcasses, while other observers had reported a total of 44 additional carcasses, for a total of 108. During the same time period, reports from various individuals of "sick" sea lions in unusual locations numbered 85.

The behavioral symptoms of this ailment were pronounced. Most animals were reluctant to swim and would even tolerate humans at close range. Many persons reported animals unable to use their hind-limbs, but closer examination revealed that most animals were just reluctant to use these appendages. Movement on land was awkward and slow. Animals usually rested in a prone position and if forced to move, stopped after a short distance and breathed heavily. The lethargy exhibited on land was also noticed in the water. Animals harassed off a beach would wade out to shallow water and lie there rather than swim away. These animals would generally haul out again as soon as possible. The tendency of these animals to seek fresh water was well documented. Individual Zalophus males were seen at the following locations: 8 kilometers up the Coquille River, near the outlet of the Empire sewage plant, at the mouth of a small stream at Sunset Bay, 13 kilometers up the Coos River,

near a highway drainage at the north cove of Cape Arago, at Tenmile Creek, at Whiskey Run, 14 kilometers up the Columbia River, 2 kilometers up the Siuslaw River, and 16 kilometers up Alsea Bay.

Clinical and Diagnostic Aspects of the Disease

All of the animals collected which exhibited the afore-mentioned behaviors, (n = 10) showed clinical signs of serious infection. Selected medical data of sacrificed animals were compared with norms described by Hubbard (1968). General clinical symptoms of sick animals included: an elevated temperature, high white blood cell count (WBC), and high blood urea nitrogen (BUN). A high BUN is indicative of renal inadequacy. No stomach contents of any kind were found in any sacrificed animals during this sickness. The only obvious lesions observed during necropsy were of the kidneys, which appeared pale compared to normal sea lion kidneys (off-white as compared with red-purple). Vedros et al. (1971) suspected that a Leptospira species was responsible for the affliction observed in Zalophus males during this period. They demonstrated the presence of large numbers of spirochetes in silver-stained kidney sections and high antibody titers to various Leptospira species (Table 6). The behavioral symptoms that I observed along the Oregon coast would be compatible with such a diagnosis. However, it should be emphasized that prior to this ailment, no information had been gathered on the antibody titers of normal subjects and that investigations made since the fall of 1970 have revealed a variety of microorganisms present in such numbers that they would constitute a serious

TABLE 6. Antibody titers to Leptospira species in animals with the acute stage of the disease and in convalescent and normal California sea lions. Results are reported as the highest dilution in which 50 percent or more of the cells agglutinated in the microscopic agglutination test. Tests on serums from sick and convalescent animals were performed through the courtesy of the National Animal Diseases Laboratory, Ames, Iowa. Serum obtained 2 weeks after treatment of animal No. 9 is termed convalescent. Results with individual serums from five healthy sea lions held in captivity are termed normal (from Vedros et al., 1971).

Animal No.	Antibody titers to <u>Leptospira</u> species			
	<u>pomona</u>	<u>icterohaemorrhagiae</u>	<u>grippotyphosa</u>	<u>autumnalis</u>
1	10,000	1,000	1,000	1,000
2	100,000	1,000	1,000	10,000
3	10,000	1,000	1,000	10,000
4	10,000	1,000	0	10,000
5	1,000	1,000	1,000	1,000
6	10,000	0	0	1,000
7	10,000	1,000	1,000	10,000
8	100,000	1,000	1,000	10,000
9	10,000	1,000	1,000	1,000
Convalescent	10,000	1,000	1,000	1,000
Normal	0	0	0	0

health hazard to most animals (Vedros, pers. comm.). Vedros et al. (1971) used serums taken from 5 healthy Zalophus of similar age held in captivity prior to the 1970 sickness as "normals." The lack of agglutinating antibodies to Leptospira in this group does not mean that these animals never had leptospirosis. If they had had leptospirosis in the past, the active immunity acquired from previous exposure would not necessarily show up as a high antibody titer. The data for a convalescent animal is probably misleading since individual Zalophus were observed to have symptoms for more than two months, and data to be presented later suggest that the illness could have continued much longer than this. That the "convalescent animal" studied by Vedros et al.

(1970) died, casts doubt on the judgment of its convalescence. No treatment of captive animals seemed to be effective, and only one such animal survived. Its survival may have been due to a copious supply of fresh water and "natural factors" more than anything else (Hubbard, pers. comm.).

The age distribution of animals found dead on the beach and those sick animals which were killed during the fall and winter of 1970-1971 is shown in Figure 13 and can be compared with the age distribution of Zalophus killed during feeding studies and found on the beaches prior to the fall of 1970 (Figure 14). The latter may be biased by the collection techniques if there were age-class differences in feeding activity and natural mortalities. Although the exact age distribution of Zalophus males normally occurring along the Oregon coast is not known, the distribution of dead animals (on the basis of physical appearances) resembled the natural distribution, except that very old individuals were not represented in the "beach carcass" sample. The majority of the animals found dead in Oregon had well developed sagittal crests, a skull characteristic which does not start to develop until 5 years of age (Orr et al., 1970). Over 85 percent of the Zalophus in Oregon during 1968, 1969, and 1970 possessed well developed sagittal crests indicating that young Zalophus do not travel as far north as Oregon in great numbers. Because female Zalophus resemble immature males, this also provides an upper limit for the number of females possibly this far north. The sick and dead Zalophus observed in California were almost exclusively subadults (very few animals were seen with

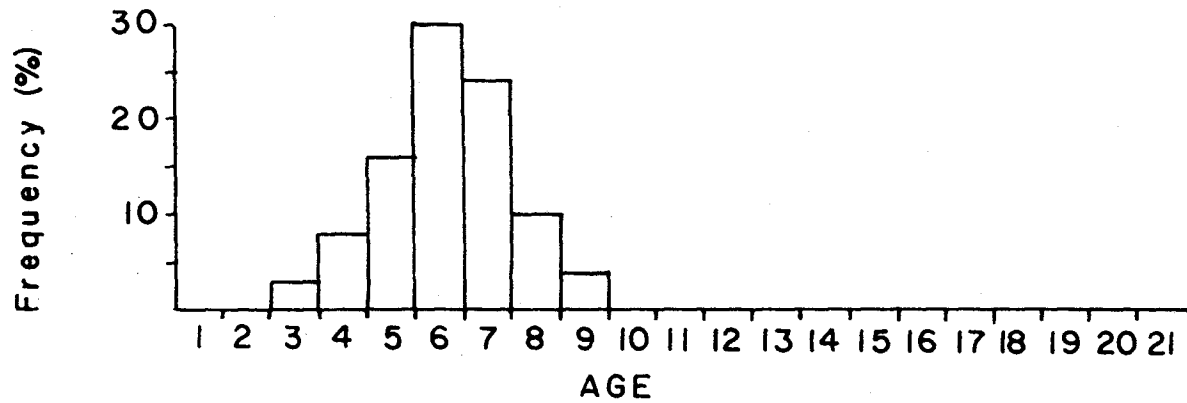


Figure 13. Age distribution of dead Zalophus - 1970

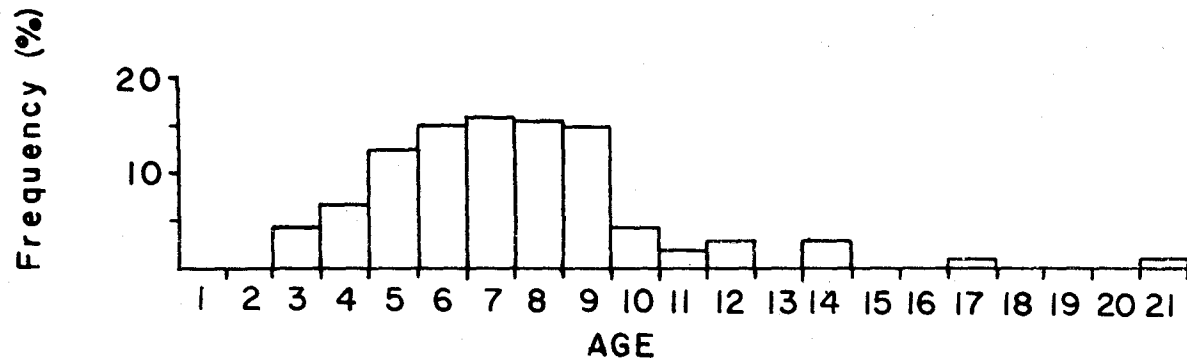


Figure 14. Age distribution of collected and dead Zalophus - 1968 and 1969.

sagittal crests [Hubbard, pers. comm.]), although only 15 percent of the population at nearby Año Nuevo Island is in this age class (Orr, 1965).

Close observation of Oregon hauling areas revealed a 90 percent morbidity (that percentage of the population which was sick) as demonstrated by extremely lethargic Zalophus. The remaining 10 percent represented all of the largest males present (presumably also the oldest males). The morbidity, that percentage of the population which was sick, was therefore 90 percent. Old males may have gained an immunity by prior exposure to the causative agent. According to Vedros et al., (1971) an increased mortality of Zalophus was observed in 1947. The tentative diagnosis at that time was bacterial pneumonia; however, if the causative agent of the 1947 and 1970 afflictions were both the same, it could be expected that animals surviving the 1947 episode, would be immune to it during 1970. It is unlikely that very many animals of that age class (23 years and older) were alive during 1970. The oldest Zalophus specimen that I have collected was 21 years of age according to the dental annuli. The next oldest was 17. I know of no specimens older than these. The construction of a good life table for Zalophus would require a tremendous amount of work. Without accurate information on the age class distribution of the population, it is not possible to accurately determine individual age class mortality rates.

A minimum mortality estimate was made based on the number of carcasses found along the beach and the maximum population censused along the Oregon coast during the fall of 1970. There probably were

carcasses on the beach which were missed and it is doubtful that all dead animals washed up on the beach. The mortalities numbered 251 representing almost 10 percent of the maximum census count for this species of 2600 individuals. The apparent distribution of these carcasses was biased because reports came only from areas frequented by humans. The high frequency of carcasses found around Coos Bay was probably the result of my intensive search of the large accessible beaches in that area. Reports of carcasses were most common during weekends, when more people used the beaches. Increased public awareness of the sea lion dilemma through the press probably increased reports, making it impossible to determine if there was a peak in fatalities. Very few observations of sickness or fatalities among sea lions were reported for the southern California coast. Data from central and northern California (Hubbard, pers. comm.) indicate that the affliction may have been less serious than among animals in Oregon. In total, 315 strandings and 125 dead animals were reported from California, while over 2000 animals exhibited symptoms in Oregon and 251 animals were found dead.

The diagnosis of leptospirosis on the basis of the behavioral symptoms and the extremely high titers to this microorganism was further supported by an increase in the number of premature births (a characteristic symptom of leptospirosis) among Zalophus at San Nicholas Island during the 1970 breeding season before any other problems in this species were recognized (Odell, 1970, 1972). "Premature pups" are defined as pups born before the normal pupping season which are

either born dead or die soon after birth.

While premature pupping has been reported for several other pinniped species (Rand, 1955; Kenyon and Rice, 1959; Rice, 1960; Craig, 1964; Marlow, 1968; Odell, 1972), there are no comparative mortality data for premature Zalophus pups prior to 1970 (Odell, 1970; Simpson and Gilmartin, 1970). Odell (1970) cites field observations by G. A. Bartholomew indicating that small numbers of premature pups have been observed since 1948. Odell's data show a dramatic difference in the premature pupping rate for 1969 and 1970. In a population of approximately 5,500 females during both years, 135 premature pups were observed in 1969, while 442 dead pups were counted during 1970 (an 8% pup mortality, assuming all females had pups). Premature pupping continued at almost the same rate during 1971, when 391 dead pups were observed among 5,200 females.

The observed abortions in Zalophus may fall within the normal range for that species. High antibody titers to Leptospira species have not been demonstrated in Zalophus pups or females and overt symptoms of sickness, resembling those observed among males, have not been reported among females. While some sex specific diseases are known, leptospirosis is not one of these. If abortions were caused as a result of a Leptospira infection, titers in females and perhaps in pups should have been demonstrable. This information would have strengthened the diagnosis of leptospirosis-induced abortions but such data were not obtained. Because of the southern, offshore location of most females of this species, access to animals for titer work was extremely limited.

The concentrations of various environmental residues in premature pups was investigated by Simpson and Gilmartin (1970), who concluded that the concentrations were low. Their studies included chlorinated hydrocarbons, which have been highly suspected to cause serious abnormalities in offspring and irregularities in the birth and breeding process of many species of mammals and birds. Unfortunately, females which have pupped prematurely have not yet been tested.

It has been suggested by Vedros et al. (1970) that leptospirosis may be epizootic in Zalophus. The Leptospira species found in sea lions has been pure cultured recently and has been identified as Leptospira pomona (Hubbard, pers. comm.). L. pomona is common in many domestic animals and is often an occupational disease for farmers and veterinarians. The bacteria are transmitted via the urine. Sea lions could easily transmit it among themselves as they often urinate and defecate on the hauling grounds and rookeries. These microorganisms are very difficult to culture under laboratory conditions, and so the means of initial transmission of the bacteria to sea lions must have been fairly direct. One explanation may be that sea lions were infected from wild goats and sheep which have recently been introduced to many of the California Channel Islands. Tests for Leptospira species on these animals have not been made.

The role of biological and chemical agents acting as predisposing factors to disease in sea lions is as yet unknown. The possibility that toxic heavy metals, chlorinated hydrocarbons, or polychlorinated biphenols (PCBs) were responsible for the symptoms of male Zalophus was

investigated (Mate et al., in press). Otariids concentrate heavy metals and pesticide residues as do other mammals, birds, and fish. Because most industrial and agricultural wastes eventually go to the ocean, the marine food web is exposed to many toxic substances. Many of these toxicants have long biological half-lives, which result in a phenomenon known as food chain magnification. In such a scheme, each higher trophic level in the food chain receives proportionately higher concentrations of these residues from its food species, resulting in very high concentrations at the top carnivore level. Sea lions represent one of the highest trophic levels in the ocean and were therefore expected to have high concentrations of such residues.

To explore the possibility of toxification a sample of 10 sick male Zalophus was killed for tissue analysis and clinical evaluation of various components of the blood. The tissues taken from these specimens were uniformly higher in mercury, cadmium, chlorinated hydrocarbons and PCBs than similar tissues from animals of lower trophic levels in the marine food chain or similar trophic level terrestrial mammals. The mercury results were similar to those recently reported for the northern fur seal, Callorhinus ursinus (Anas, in press). The highest levels of mercury were found in the liver, while high values for cadmium and chlorinated hydrocarbons were in the kidney and fat respectively. During 1971, a sample of 8 randomly selected animals among apparently healthy Zalophus was used to compare tissue concentrations with the 1970 data. The animals were similar in age to those sampled during 1970 and were taken during the same general time of the year. A

detailed account of the findings may be found in Mate et al. (in press); it is sufficient to say that there was a mathematically significant difference in concentrations between sick animals taken during 1970 and presumably healthy individuals taken during 1971. The biological significance, however, is unknown. It is noteworthy that the weakest animal observed with symptoms during 1970 also had the lowest mercury concentration in its liver. It therefore seems unlikely that the Zalophus population was suffering as a direct result of these particular toxicants. This does not eliminate the possibility that the animals involved were weakened by high concentrations of these substances or others not tested for.

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