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A REVIEW OF THE POPULATION ECOLOGY OF THE NORTHERN ELEPHANT SEAL *(Mirounga angustirostris)*

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U.S. DEPARTMENT OF COMMERCE
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A REVIEW OF THE POPULATION ECOLOGY OF THE NORTHERN ELEPHANT SEAL (*Mirounga angustirostris*)

Prepared

by

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INTRODUCTION

The northern elephant seal, Mirounga angustirostris (Gill) 1866, is one of the largest living pinnipeds, matched in size only by the congeneric southern elephant seal, M. leonina. Males of the northern species reach a length of 14 to 16 feet, and may weigh more than 5,000 pounds. The female is considerably smaller, reaching a length of seven to eleven feet, and weighing about 2,000 pounds. The species derives its common name from the males' large inflatable proboscis. Its large round eyes are apparently an adaptation to obtaining food at considerable depths.

The species ranges along the Pacific coast of North America from Baja California to southern Alaska. Breeding rookeries extend over a considerably shorter distance: from San Benito Islands, Baja California, to the Farallon Islands, California.

Pronounced seasonal variations in the numbers and age classes of animals ashore occur. Most adults and immatures haul out on land to molt from May through August. The breeding segment of the population returns to land during a December - January pupping period.

The pregnancy rate among adult females is apparently quite high, although quantitative data on this subject are not available. Pup mortality varies with the degree of crowding on the beaches. Mortality factors in other age classes include predation, accidents, willful slaughter, and possibly parasitism. The role of these mortality factors in molding population structure is not known. A number of parasites have been found in northern elephant seals.

Three subpopulations are considered: Baja California, Channel Islands, and Central California. The latter two subpopulations were extirpated by sealers in the nineteenth century, while the Baja California subpopulation was reduced to very low numbers. With protection, the species has reoccupied most of its previous range. Estimates of the total population size in the early 1970's range from 31,500 to 37,000 animals. Most of these seals are in the Baja California subpopulation.

The northern elephant seal currently shows none of the polymorphism in serum proteins observed in other species of pinnipeds. This is thought to be the result of the historical decimation, and may indicate little genetic plasticity exists in the population today. This may decrease the possible responses of the species to potential long-term environmental changes or to environmental pollution.

ANNUAL CYCLE

The annual pattern of shore occupation by northern elephant seals shows pronounced seasonal variations in regard to total numbers and the proportions of various age and sex categories. The cycle has been shown to be identical on Año Nuevo Island (Le Boeuf 1974, Le Boeuf *et al* 1972, 1974) (Fig. 1) and San Nicolas Island (Odell 1974) (Fig. 2), and is thought to be characteristic of the species. Oceanic movements of elephant seals are less well understood, but sightings suggest distinct patterns for the two sexes.

The onshore population is at its lowest in July and August. Numbers increase gradually and reach a *fall peak* in November as the beaches are occupied almost exclusively by sexually immature animals of both sexes. Numbers decline again in early December as immatures leave the shore, but experience a rapid upswing in late December and early January as the breeding segment of the population comes ashore. The birth of pups swells the size of the rookeries, and a *winter peak* in numbers is recorded in February. A postbreeding decline in numbers occurs in March as the adults return to sea, leaving only the pups ashore. A *spring peak* in numbers occurs in late April and early May as immatures, notably yearlings, and adult females come on to land to molt. This influx of adults and immatures masks the movement of pups to sea. The spring peak represents the greatest annual congregation of elephant seals ashore.

Oceanic sightings suggest that adult and immature male elephant seals are abundant in waters of the North Pacific Ocean from southern Alaska to Oregon in April, May and September. Months of most frequent sightings correspond well with lows in the abundance of males on land. Records of

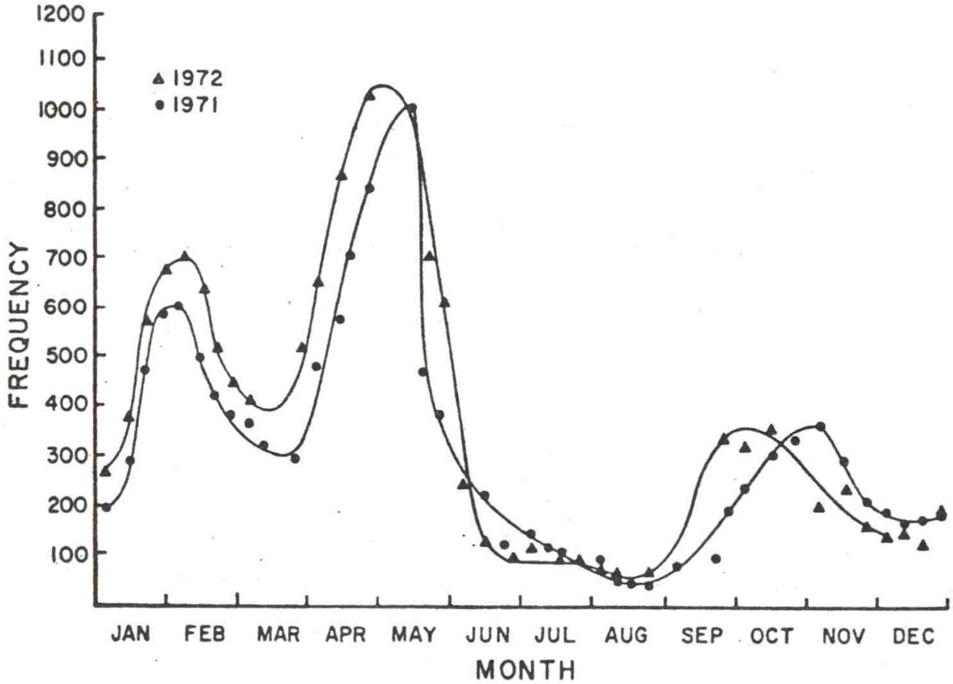

Fig. 1. Seasonal abundance of northern elephant seals on Año Nuevo Island, California (from Le Boeuf <u>et al</u> 1974).

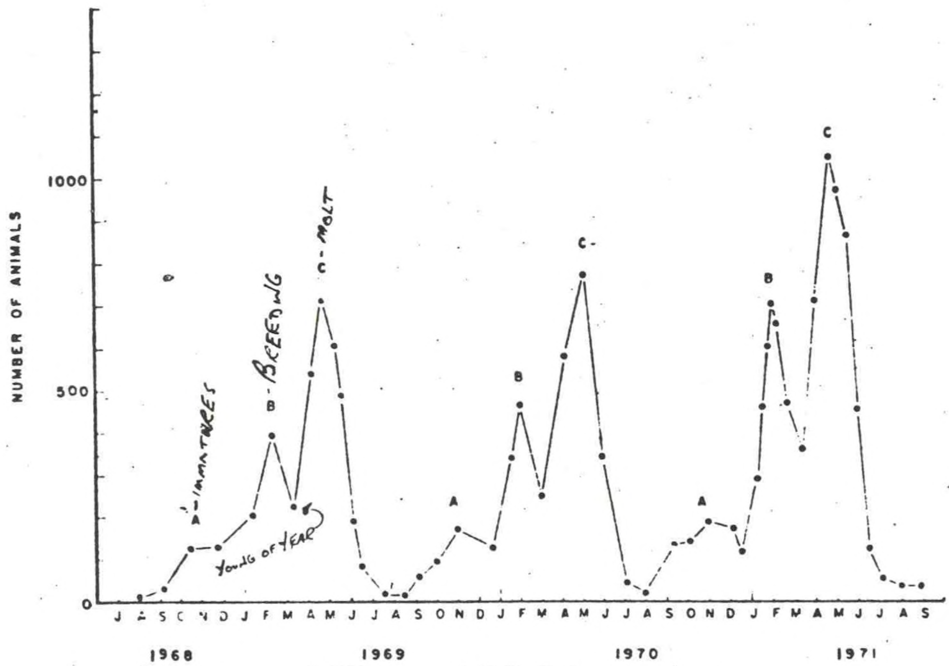

Fig. 2. Seasonal abundance of northern elephant seals on San Nicolas Island, California (from Odell 1974).

the oceanic movements of adult or immature female elephant seals were not uncovered.

Fall Peak

A fall peak composed chiefly of immature animals occurs in October and November. The immatures leave the beaches before the bulk of the breeding adults comes ashore. The function of the fall peak is not known (Odell 1974).

Winter Peak

The adult males begin to return to the breeding rookeries in late November and early December (Le Boeuf 1972, Odell 1974) where they quickly establish a social hierarchy through a combination of threats, fights, and chases. Such aggressive behavior, which continues throughout the winter peak, tends to space males out over the beaches (Le Boeuf 1972). Pregnant females begin to arrive in late December (Le Boeuf 1972). The females congregate in tight groups. The degree to which a male is able to keep consort with a female group is dependent on his status in the social hierarchy: the most dominant males being in association continuously until the last females leave the rookeries in mid-March (Le Boeuf 1972).

A single precocial pup, weighing about 65 pounds, is born an average of seven days after the female comes ashore (Le Boeuf 1972, Le Boeuf et al 1972). Pups are normally suckled every day until weaning 27 to 29 days after birth (Le Boeuf 1972, Le Boeuf et al 1972). At about this time the female comes into estrus and mates with a socially dominant male. Females leave the beaches by mid-March after being ashore an average of 34 days (Le Boeuf 1972, Le Boeuf et al 1972). The adult males return to sea no later than early April, having been ashore about 75 days (Le Boeuf 1972, Odell 1974).

Pups molt from a black natal pelage to the gray pelage of older animals between 28 and 42 days after birth. By mid-March pups are the sole remaining occupants of the breeding rookeries. At this time, they begin to enter the shallow water offshore and presumably begin feeding. Most pups leave their rookery of birth by the end of April (Le Boeuf 1972, Odell 1974). Data from tag returns suggest a northward shift in distribution. In April and May, pups born on the islands off Baja California are sighted on the Channel Islands, while pups from the Channel Islands are recorded off Central California (Le Boeuf et al 1972).

Spring Peak

In late March and April, adult and immature, notably yearling, elephant seals begin to return to the beaches to molt. Most pups have completed their postnatal molt and go to sea prior to the arrival or adults and immatures (Odell 1974). The numbers of animals ashore reaches a peak sometime between mid-April and mid-May (Le Boeuf 1974, Le Boeuf et al 1972, 1974, Odell 1974). This peak represents the greatest annual congregation of elephant seals on land.

Although there is some overlap, the sequence of molt among adults and immatures is: adult females, immatures of both sexes, and adult males, with the oldest being last (Odell 1974). Females return to shore 50 to 69 days after leaving the breeding congregation (Odell 1974), with a maximum influx in the first week of April. The females molt over a period of 2 - 3 weeks. Immatures begin to arrive by mid-April. A single immature, marked by Odell (1974), had been away from shore for 134 days when resighted. Adult males begin to return to shore in late June, after being at sea about 124 days (Odell 1974).

Oceanic Sightings

Bartholomew (1952) noted that undisturbed northern elephant seals enter the water on an individual basis, and inferred that they are solitary at sea. Sight records confirm that they are normally solitary. In one instance, three northern elephant seals of unspecified age and sex were sighted together in Hecata Strait, British Columbia (Pike and MacAskie 1969). All other oceanic sightings of northern elephant seals are of solitary animals (Table 1).

All oceanic sightings, with identification of sex, are of adult males. It is easy to imagine that the male's large proboscis would facilitate confirmed sightings. However, the limited number of published records of beached animals is solely of adult males. Willit (1943) reported a male northern elephant seal washed ashore at Kasaan, Prince of Wales Island, Alaska, while a second male was beached by killer whales (*Orcinus orca*) at Ucluelet, Vancouver Island, British Columbia (Cowan and Guiget 1952). Another male washed ashore near Bando, Oregon (Frieburg and Dumas 1954). Finally both adult and immature males, but no females, have been recorded coming ashore in Oregon (Mate 1969, 1970).

All records show a shift northward from the breeding rookeries in April - May following the winter peak, and again in September - October after the spring peak (Table 1, Fig. 3). Adult males return south to the rookeries to molt in late June and July (Odell 1974). Smith (1973: 166)

Table 1. Oceanic records of northern elephant seals by month of sighting.

DATE		NUMBER	SEX	LOCATION	SOURCE
1960	23 February	-	-	Quatsino Sound, British Columbia	Pike and MacAskie 1969
	3 March	-	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
	28 March	-	-	Laredo Inlet, British Columbia	Pike and MacAskie 1969
	29 March	1	male	Cape Flattery, Washington	Sanger 1965
1934	25 April	1	male	Hecate Strait, British Columbia	Cowan and Carl 1945
1958	9 April	-	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
1959	27 April	-	-	Graham Reach, British Columbia	Pike and MacAskie 1969
	30 April	-	-	Principe Channel, British Columbia	Pike and MacAskie 1969
1960	17 April	-	-	Grenville Channel, British Columbia	Pike and MacAskie 1969
1961	6 April	-	-	Brockton Island, British Columbia	Pike and MacAskie 1969
	28 April	-	-	Ashdown Island, British Columbia	Pike and MacAskie 1969
1963	21 April	-	male	Puget Sound, Washington	Scheffer and Kenyon 1963
1964	26 April	3	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
1934	14 May	1	male	Hecate Strait, British Columbia	Cowan and Carl 1945
1957	7 May	1	-	Chatham Strait, Kuiu Island, Alaska	Brooks 1963
1960	27 May	-	-	Estevan Point, 25 mi. S. British Columbia	Pike and MacAskie 1969

Table 1 (Continued)

DATE		NUMBER	SEX	LOCATION	SOURCE
1961	7 May	-	-	Wright Sound, British Columbia	Pike and MacAskie 1969
	9 May	-	-	Caamano Sound, British Columbia	Pike and MacAskie 1969
	11 May	-	-	Caamano Sound, British Columbia	Pike and MacAskie 1969
1962	7 May	-	-	Wright Sound, British Columbia	Pike and MacAskie 1969
1960	12 June	-	-	Queen Charlotte Sound, British Columbia	Pike and MacAskie 1969
	18 June	-	-	Quatsino Sound, British Columbia	Pike and MacAskie 1969
	23 July	-	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
	25 July	-	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
1941	- August	1	male	Cape Flattery, 70 miles SW.,Washington	Cowan and Carl 1945
1960	22 August	-	-	Tasu Sound, British Columbia	Pike and MacAskie 1969
1963	26 August	3	1 male	Florence, 35 mi. W., Oregon	Scheffer 1964
1929	20 September	1	male	San Diego, 40 mi. W., California	Huey 1930b
1944	22 September	1	male	Queen Charlotte Strait, British Columbia	Cowan and Carl 1945
1955	7 September	1	-	Chatham Strait, Kiui Island, Alaska	Brooks 1963
1958	1 September	-	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
1959	8 September	-	-	Lewis Pass, British Columbia	Pike and MacAskie 1969
	27 September	-	-	Luscombe Inlet, British Columbia	Pike and MacAskie 1969

Table 1 (Continued)

DATE		NUMBER	SEX	LOCATION	SOURCE
1961	10 September	-	-	Graham Reach, British Columbia	Pike and MacAskie 1969
	15-16 September	-	-	Hecate Strait, British Columbia	Pike and MacAskie 1969
	16 September	-	-	Tolmie Channel, British Columbia	Pike and MacAskie 1969
1968	2 September	1	male	Puget Sound, Washington	Craddock 1969
1960	18 October	-	-	Goletas Channel, British Columbia	Pike and MacAskie 1969
1961	8 October	-	-	Hastings Point, British Columbia	Pike and MacAskie 1969
	16 October	-	-	Dawson Inlet, British Columbia	Pike and MacAskie 1969

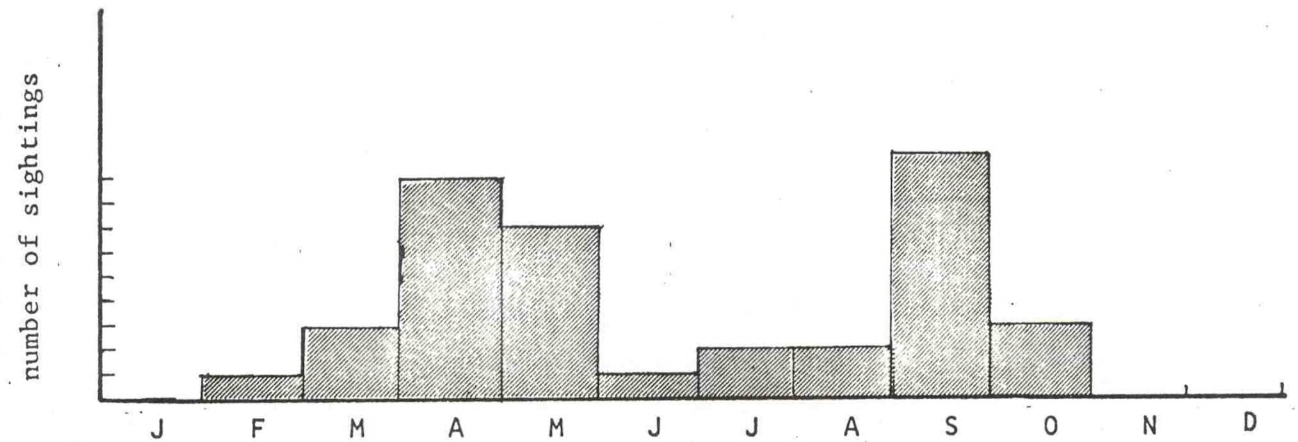

Fig. 3. Number of oceanic sightings of northern elephant seals by month of sighting.

notes that, "British Columbia is a regular wintering area for some of the populations." Two sick individuals were taken off Vancouver Island, British Columbia, in early December, 1975 (C.L. Hubbs, Scripps Institution of Oceanography La Jolla, California 92038, pers. comm.).

A northward movement is known to have occurred in the 1800's, prior to commercial exploitation. Maka Indians traditionally hunted northern elephant seals each spring off the Strait of Juan de Fuca, British Columbia (Cowan and Carl 1945). Scanty evidence suggests that a shift northward continued when population numbers were relatively low. Huey (1930b) reported a male taken off San Diego in September, 1929, at a time when breeding was restricted to Guadalupe Island. Fishermen began to report the species off the coasts of Oregon and Washington in the mid-1930's (Hubbs, pers. comm.) while fishing for albacore.

The pattern of sightings suggests that an important feeding ground for male northern elephant seals stretches from Quatsino Sound off western Vancouver Island to Hecate Strait and the broad channels east of the strait, and as far north as Kuiu Island, Alaska (Manville and Young 1965, Pike and MacAskie 1969) (Fig. 4).

FEEDING HABITS

Data on the feeding habits of northern elephant seals are sparse. Examination of the stomach contents of an elephant seal taken off San Diego, California, revealed that the animal had been feeding on slow swimming organisms found at a depth of 50 to 100 fathoms, such as rat fish (Hydrolagus collei), dogfish shark (Squalus sucklii), puffer shark (Catulus uter), and squid (Loligo opalescens) (Huey 1930b). Examination of additional stomach contents have confirmed this basic diet in other regions

Fig. 4. Distribution of northern elephant seals outside of their breeding range.

(Hubbs, pers. comm., Morejohn and Blatz 1970). Comparisons of the diet to available food supply as estimated by trawl line catches suggest selective feeding (Morejohn and Blatz 1970). The ability of northern elephant seals to descend to considerable depths was confirmed by the accidental taking of three individuals on a hook line set at 100 fathoms (Scheffer 1964).

Northern elephant seals may also be opportunistic surface feeders. Individual animals have been sighted in groups of Pacific white sided dolphin (Lagenorhynchus obliquidens) feeding on anchovy (Engralis morday) off the Channel Islands, California (Brown and Norris 1956).

REPRODUCTION

Nulliparous northern elephant seals normally mate at the end of their third year, although some may do so a year earlier at some location other than the rookery (Le Boeuf pers. comm.). Pregnant females begin to arrive on the rookeries in late December, about eleven months after conception (Bartholomew 1952). Their numbers build to a peak in January (Le Boeuf 1972, Odell 1974). A single pup is born an average of seven days after the female returns to shore (Le Boeuf 1972, Le Boeuf et al 1972). About 50% of the pups are born during the last two weeks of January (Le Boeuf et al 1972). Pups are suckled until the female returns to sea 27 to 29 days after birth (Le Boeuf 1972, Le Boeuf et al 1972). Most parous females mate prior to their departure from the rookeries (Le Boeuf 1972). However, postparturient females that did not nurse their offspring regularly do not breed before returning to sea (Le Boeuf et al 1972).

The reproductive cycle appears to be instrinsic. Bartholomew

(1952: 338) noted that the, "breeding season of parous females is determined primarily by two internally regulated factors: the duration of pregnancy (approximately 11 months), and the interval between parturition and estrus."

Data on pregnancy rates are not available.

MORTALITY

Observations of northern elephant seals have resulted in identification of a number of mortality factors. However, a synthesis of the role of various mortality factors in molding population structure has not been undertaken. The present level of knowledge permits little more than a listing of known causes of death.

In utero mortality -- Records of premature births among northern elephant seals do not exist, although it is conceivable that premature births could occur at sea (Le Boeuf et al 1972). Stillbirths are not common: four have been recorded in approximately 1,050 births observed on Ano Nuevo Island (Le Boeuf et al 1972).

Neonatal mortality -- Mortality of pups on the rookeries may be higher than for any other segment of the population. As noted by Bartholomew (1952), neonatal mortality is fairly common and increases sharply with the degree of crowding in the rookery. There are only two published estimates of pup mortality rates. Approximately four percent of the pups born on San Nicolas Island in 1970 and 1971 perished soon after birth (Odell 1971). Total pup mortality on Año Nuevo Island from 1968 to 1972 was 14.2% (Le Boeuf et al 1972). Both rookeries are uncrowded compared to congestion on the rookeries of Guadalupe and San Miguel Islands (Le Boeuf, pers. comm.).

Pups die from trampling and bite wounds and from starvation (Bartholomew 1952, Le Boeuf et al 1972). Forty percent of the pups observed on Año Nuevo Island became separated from their mothers (Le Boeuf et al 1972). Pups moving about the rookery in search of a receptive suckling female are more exposed to trampling and bite wounds. Approximately 70% of the orphaned pups died in the first month of life (Le Boeuf et al 1972). About 40% of this mortality was the direct result of being crushed or bitten by adult males. Most of the orphaned pups that survived were adopted by lactating females (Le Boeuf et al 1972), however, most were considerably stunted in growth, and probably died within the first year of life (Le Boeuf et al 1972).

Other mortality factors -- Although maximum longevity in northern elephant seals is at least 14 years, 86 - 93% of the free-living males may die before six or seven years of age (Le Boeuf 1974). No comparable figures are available for the female segment of the population. Causes of mortality vary and include predation, accidents, and indiscriminate slaughter.

Northern elephant seals are taken by killer whales and sharks, particularly the great white shark (*Carcharodon carcharias*). Four of ten killer whales taken off the California coast had the remains of seven elephant seals in their stomachs. The remaining six had not fed on elephant seals (Rice 1968). Specimens were identified by vibrissae and claws, suggesting that the carcasses had not been swallowed whole. In addition, killer whales beached an adult northern elephant seal at Ucluelet, Vancouver Island, British Columbia (Cowan and Guiget 1952). Shark attacks may be quite common. Townsend (1885: 92) was told by sealers that, "fully one-fourth of female sea elephants killed at San Cristobal Bay bore unmistakable traces of the teeth of sharks." A great white shark of just over 18 feet on display at Sea World, San Diego contained the remains of an adult female, or immature male, northern elephant seal at the time of its capture (Hubbs, pers. comm.).

The following examples give some idea of the variety of accidental deaths: 1) several adults were crushed to death on the beaches of Guadalupe Island by boulders falling from the cliffs above (Fitch and Wilson 1949); 2) an adult female washed ashore at La Jolla, California, after being struck and killed by the propeller of a boat (Hubbs, pers. comm.); and 3) a subadult male drowned after being hooked on a fishing line off Washington (Scheffer 1964). Accidents involving northern elephant seals and man will probably increase with increase in human utilization of coastal waters.

Indiscriminate slaughter occasionally takes its toll of pinnipeds. Over a hundred sea lions and seals, including elephant seals, were shot on Santa Barbara Island, California, in June 1965 (Hubbs, pers. comm.).

PARASITES AND DISEASES

Internal parasites of northern elephant seals include two species of trematodes, four species of nematodes, and an acanthocephelan (Table 2). The turbinates are often infected with mites. Maladies attributable to these parasites are largely unknown; however, *Parafilaroides* sp. may have caused pneumonia in a young male (Johnston and Ridgway 1969, Sweeney 1974). *Parafilaroides decorus* causes pneumonia in northern sea lions (*Eumetopias jubata*) (Sweeney 1974).

Table 2. Parasites of the northern elephant seal.

Parasite	Organ Affected	Source
TREMATODES		
Cryptocotyle lingua	intestine	Dailey and Brownell 1972
Zalphotrema hepaticum	liver	Dailey and Brownell 1972
NEMATODES		
Anasakis similis	stomach	Dailey and Brownell 1972
Porrocaecum decipiens	stomach	Dailey and Brownell 1972
Contracaecum osculatum	stomach	Dailey and Brownell 1972
Parafilaroides sp.	lungs	Sweeney 1974
ACANTHOCEPHALA		
Corynosoma sp.		Dailey and Brownell 1972
ACARINA		
Halarchne miroungae	turbinates	Ferris 1925

A young male elephant seal with a severe eye infection (cause unknown) was shot near Ucluelet, Vancouver Island, British Columbia, in December 1975 (Hubbs, pers. comm.).

An unidentified fungal disease causing depigmented lesions on the epidermis has been observed in "several" captive northern elephant seals. The lesions disappear with the beginning of molt (Sweeney 1974).

THE POPULATION

The northern elephant seal is believed to have originally bred on islands and isolated sections of the mainland along 1,000 miles of North America's Pacific coastline from Cape Lazaro, Baja California, to the Farallon Islands, (Scammon 1870) or to Point Reyes, California (Scammon 1874). Commercial exploitation from the early 1800's until about 1860, and again briefly in the 1880's (Townsend 1885), decimated numbers and greatly diminished the populations' range. All seals were eliminated from the islands off central California by the end of the 1830's (Doughty 1971). Northern elephant seals were still reported from the Channel Islands, California, until 1880 (Allen 1880), but apparently were extirpated soon thereafter. By the mid-1880's the species survived only off Baja California. The numbers have increased continuously from a low of approximately 100 individuals at the turn of the century (Bartholomew and Hubbs 1960). At present, northern elephant seals breed from the San Benitos Islands, Baja California, to the Farallon Islands, California (Fig. 5).

Subpopulations

Geographical considerations and historical events have combined to influence the distribution and status of the northern elephant seal within

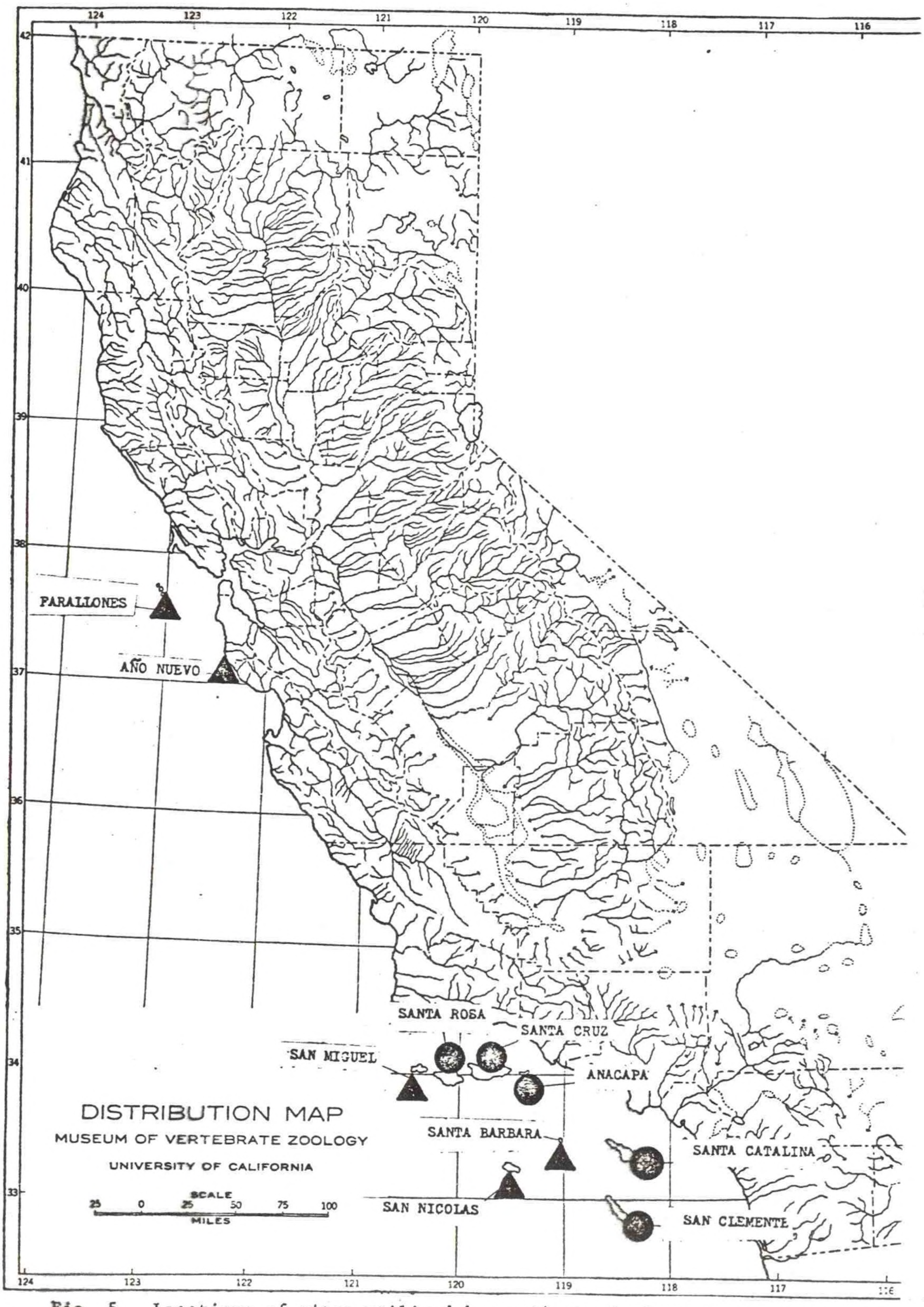

Fig. 5. Locations of sites utilized by northern elephant seals along the coast of California and Baja California: triangles are rookeries, circles are non-breeding sites.

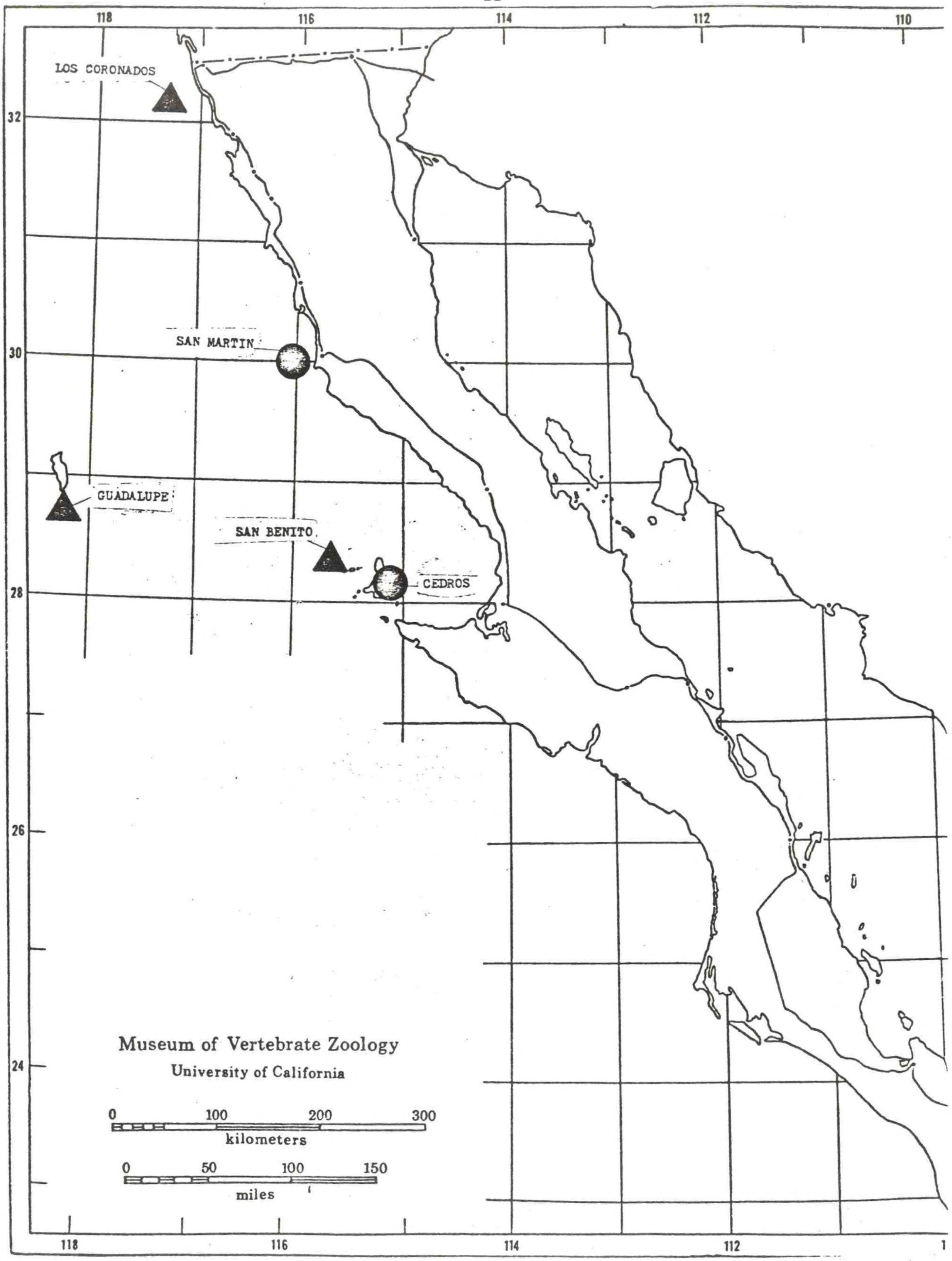

Fig. 5. Continued.

its present range. It is proposed that the total population be treated as three subpopulations: a Baja California subpopulation, a Channel Islands subpopulation, and a Central California subpopulation. The Baja California subpopulation consists of northern elephant seals breeding on Guadalupe Island, the San Benito Islands, and San Martin Island. The latter subpopulation is the largest. The Channel Islands subpopulation, which is intermediate in size, embraces animals breeding on the islands of Los Coronados, San Nicolas, Santa Barbara, and San Miguel. The Central California subpopulation includes animals breeding on Año Nuevo Island, the adjacent mainland, and the Farallon Islands. It is the smallest of the subpopulations.

Pattern of Rookery Recolonization and Current Distribution

Commercial exploitation of the northern elephant seal, from the early 1800's until approximately 1860, completely eliminated the central California subpopulation, while numbers in the Channel Islands and Baja California subpopulations were reduced to very low levels. The Channel Islands subpopulation was restricted to Santa Barbara Island by 1880 (Allen 1880). It apparently ceased to exist soon after that time. By 1880, numbers of northern elephant seals off Baja California had increased somewhat. Rookeries occurred on the mainland of Baja California, at San Cristobal Bay, and on Guadalupe Island. Both of these rookeries were subjected to commercial harvesting between 1880 and 1884 (Townsend 1885, 1912) (Table 3).

Detailed studies of recolonization (Le Boeuf *et al* 1974) have shown that such sites are often occupied sporadically by small groups of animals

Table 3. Censuses of the Baja California subpopulation

YEAR	MONTH	LOCATION[1]					COMMENTS	SOURCE
		SCB	GI	SBI	CI	SMI		
1880	Fall & Winter	30	-	-	-	-	All harvested	Townsend 1885
1882	--	40	-	-	-	-	All harvested	Townsend 1885
1883	--	110	80	-	-	-	All harvested	Townsend 1885, 1912
1884	--	129	4	-	-	-	All harvested	Townsend 1885
1892	--	-	8	-	-	-		Townsend 1889
1904	--	-	4	-	-	-		Townsend 1912
1907	June	-	40	-	-	-		Townsend 1912
1911	March	-	125	-	-	-		Townsend 1912
1918	July	-	-	6	-	-	First report of hauling out on SBI	Hanna 1925
1922	July	-	264	-	-	-	All adult males	Anthony 1924
	September	-	150	-	-	-	Total population estimated at no less than 1,000	Hanna 1925
1923	July 16	-	366	-	-	-	Total population estimate of 1,250 is conservative (Anthony 1924)	Anthony 1924 Huey 1925
1924	August 30	-	124	-	-	-		Huey 1925

Table 3 (Continued)

YEAR	MONTH	LOCATION[1]					COMMENTS	SOURCE
		SCB	GI	SBI	CI	SMI		
1926	June 23	-	465	-	-	-		Huey 1927
1929	September 27	-	469	-	-	-		Townsend 1930 Huey 1930a
1948	March 31	-	2891	700+	-	-	First record of breeding on SBI	Fitch and Wilson 1949
1950	January - February	-	4500	908	-	-		Bartholomew and Hubbs 1952
1954	November	-	899	-	-	-		Bartholomew and Hubbs 1960
1955	June	-	1786	-	-	-		Bartholomew and Hubbs 1960
1956	April	-	3466	-	-	-	Census incomplete	Berdegue 1956
	August	-	623	-	-	-		Bartholomew and Hubbs 1960
1957	February	-	5044	-	-	-		Bartholomew and Hubbs 1960
	April	-	9143	-	-	-	Subpopulation estimated at 12,650	Bartholomew and Hubbs 1960
	October	-	2540	-	-	-		Bartholomew and Hubbs 1960
	December	-	2495	-	-	-		Bartholomew and Hubbs 1960

Table 3 (Continued)

YEAR	MONTH	LOCATION[1/]					COMMENTS	SOURCE
		SCB	GI	SBI	CI	SMI		
1960	January	-	11000	-	-	-	Subpopulation estimated at 14,400	Bartholomew and Hubbs 1960
1965	January	-	10389	2860	47	0	Subpopulation estimated at 13,296	Rice et al 1965
1966	April	-	15000	-	-	-		Hubbs pers. comm.
1968	April	-	-	-	-	"small groups"	First records of hauling out on SMI	Schulz et al 1970
1968	April	-	9341	1201	39	-	Partial count on SBI	Brownell et al 1974
	June	-	1100	552	25	-		Brownell et al 1974
1969	February	-	15305	-	-	-		Hubbs, pers. comm.
1970	April	-	9127	5184	-	69		Bonnell and Pierson 1970
	May	-	-	2087	-	-		Pierson 1970
1971	May	-	-	-	-	36		Odell et al 1976[2/]
1973	February	-	-	-	-	44		Odell et al 1976[2/]

1/ SCB = San Cristobal Bay, GI = Guadalupe Island, SBI = San Benito Islands
CI = Cedros Island, SMI = San Martin Island

2/ See text footnote number one.

for several years before breeding occurs. The first breeding season on the Farallon Islands was initiated by the arrival of two pregnant adult females, but males were not seen here for over 20 days (Le Boeuf et al 1974). During the first years of recolonization, on the Farallon Islands (Le Boeuf et al 1974) and on San Nicolas Island (Bartholomew 1952), subadult males bred the females.

Baja California subpopulation -- Northern elephant seals were last recorded at San Cristobal Bay in 1884 (Townsend 1885). By 1892, this species was breeding only on Guadalupe Island.

Records on the recolonization of rookeries off Baja California are scarce. Breeding was recorded only on Guadalupe Island from 1892 to 1948 (Table 3). In the latter year, a breeding colony of over 700 animals, including pups, was discovered on the San Benito Islands (Fitch and Wilson 1949). Observations on recolonization of other rookeries (see above) suggest that such a sizable rookery would have been in existence for some time. Apparently, the rate of recolonization increased in the 1960's. Northern elephant seals were first recorded on Cedros Island in 1965 (Rice et al 1965) and on San Martin Island in 1968 (Schultz et al 1970). These rookeries remain relatively small, containing less than 100 individuals each (Odell et al 1976[1/], Brownell et al 1974). Births have not been recorded on Cedros Island (Brownell et al 1974) or San Martin Island (Odell et al 1976[1/]).

1/. Odell, D.K., S. Leatherwood, and G.A. Antonelis. 1976. Unpubl. manuscr. Census of northern elephant seals on California and Baja California islands. Unpubl. manuscr. School of Maine and Atmospheric Science, University of Miami, Miami, Florida.

The extinct rookery at San Cristobal Bay, which may have been larger than the Guadalupe Island rookery in the 1880's (Townsend 1885, 1889, 1912), has yet to be reoccupied by northern elephant seals. There are no records of elephant seals hauling out there during this century (Hubbs, pers. comm.).

Channel Island subpopulation -- Northern elephant seals were reported to be present but "nearly extinct" on Santa Barbara Island as late as 1880 (Allen 1880). Apparently they were extirpated soon thereafter.

Animals from the Baja California subpopulation were on the islands in the 1920's. The first animals were seen off Santa Cruz and Santa Catalina Islands in 1921 (Anthony 1921). It was suggested then that these animals may have escaped from captivity at Venice, California (Rowley 1921). A solitary female hauled out on San Miguel Island in 1925 (Rett 1952) (Table 4) seven years after the first sightings on San Benito Islands (Hanna 1925). A small group of northern elephant seals was sighted on Los Coronados Islands in 1936 (Scripps 1936). Sightings on the Channel Islands were sporadic through the remainder of the 1930's and 1940's (Table 4). By 1950, small groups had been recorded from San Miguel, San Nicolas, Santa Barbara, and Los Coronados islands.

Northern elephant seals reportedly were born on the Channel Islands approximately a century after the extirpation of the original stock; pups were born on San Miguel Island in 1958 (Bartholomew and Boolootian 1960), on San Nicolas Island in 1959 (Bartholomew and Boolootian 1960), and on Santa Barbara Island in 1964 (Odell 1971). Breeding of elephant seals on Los Coronados Islands was not started until 1972 (Odell et al 1976[1/]), however, rookeries are now well established here.

Table 4. Censuses of the Channel Island subpopulation

YEAR	MONTH	LOCATION[1/]					COMMENTS	SOURCE
		SMI	SNI	SBI	SCI	LCI		
1880	-	-	-	'few'	-	-		Allen 1880
1925	-	1	-	-	-	-	female	Rett 1952
1936	September	-	-	-	-	7-8		Scripps 1936
1938	-	4	-	-	-	-	yearlings	Bonnot 1951
1938	summer	13	-	-	-	-		Bartholomew 1951
1946	summer	21	-	-	-	-		Fitch and Wilson 1949
1948	June	-	-	3	-	-		Bonnot 1951
1949	April	-	-	-	-	73		Bartholomew 1950
	May	-	143	-	-	-		Bartholomew 1951
1950	April	-	168	-	-	-	mostly large young males	Bartholomew 1951
	June	50-70	-	-	-	-		Rett 1952
1957	-	-	-	-	-	-	Subpopulation estimated at 600	Bartholomew and Hubbs 1960
1958	January	-	160	-	-	-		Bartholomew and Boolootian 1960
	February	455	-	-	-	-	First pups on SMI Subpopulation estimated at between 412-683	Bartholomew and Boolootian 1960

Table 4 (Continued)

YEAR	MONTH	LOCATION[1/]					COMMENTS	SOURCE
		SMI	SNI	SBI	SCI	LCI		
1958	April	-	207	101	-			Bartholomew and Boolootian 1960
	June	328	41	40	-			Bartholomew and Boolootian 1960
1959	January	-	160	-	-		First pups on SNI	Bartholomew and Boolootian 1960
1960	-	-	-	-	-	-	Subpopulation estimated at 600	Bartholomew and Hubbs 1960
1964	February	1922	197	39	-	-	First pups on SBI	Odell 1971
	March-April	563	-	4	-	-		Rice _et al_ 1965
1965	April	3000	-	-	-	-		Carlisle 1973
	June	3000	100	-	100	-		Carlisle and Alpin 1966
1966	April	3000	-	-	-	-		Carlisle 1973
1967	April	3700	-	-	-	-		Carlisle 1973
1968	October	-	125	-	-	-		Odell 1974
1969	February	-	393	-	-	-		Odell 1974
	April	3000	-	-	-	-		Carlisle 1973
	June	1451	-	-	-	-		Frey and Alpin 1970

Table 4 (Continued)

YEAR	MONTH	LOCATION[1]					COMMENTS	SOURCE
		SMI	SNI	SBI	SCI	LCI		
1970	January	3833	-	-	-	-		Odell 1974
	February	-	467	-	-	-		Odell *et al* 1976[2]
	April	2200	-	-	-	-		Carlisle 1973
	May	-	776	-	-	-		Odell 1974
	June	2917	-	-	-	-		Carlisle and Alpin 1971
1971	January	-	702	-	-	-		Odell 1974
	February	3200	-	-	-	-		Carlisle 1973
	April	-	1050	-	-	-		Odell 1974
1972	January	-	771	-	-	-		Odell *et al* 1976[2]
	February	3500	-	-	-	-		Carlisle 1973
		4297	807	69	-	-		Odell *et al* 1976[2]
	December	3809	-	-	-	-		Odell *et al* 1976[2]
1973	February	-	-	-	-	39		Odell *et al* 1976[2]
	March	3600	-	-	-	-		Carlisle 1973
	March	-	-	-	-	25		Odell *et al* 1976[2]
	June	-	-	-	-	99		Le Boeuf *et al* 1975
1975	March	-	-	-	-	43		Le Boeuf *et al* 1975

1/ SMI = San Miguel Island, SNI = San Nicolas Island, SBI = Santa Barbara Island, SCI = Santa Catalina Island, LCI = Los Coranodos Islands

2/ See text footnote number one.

Northern elephant seals have been reported sporadically on other Channel Islands, including: Anacapa (Bartholomew and Boolootian 1960), Santa Rosa (Rice et al 1965), and San Clemente (Carlisle and Alpin 1971), however, the numbers observed have been extremely low. The greatest concentration was one of 100 northern elephant seals on San Clemente Island in June 1965 (Carlisle and Alpin 1971).

Resightings of tagged seals show that the Channel Island subpopulation continues to receive immigrants from the Baja California subpopulation (Le Boeuf, pers. comm.). Concurrently, Channel Island animals have colonized the central California islands.

Central California subpopulation -- Northern elephant seals occurred historically as far north as Point Reyes, California (Scammon 1874). The species was hunted to extinction on the Farallon Islands between 1807 and the late 1830's (Doughty 1971).

The first, recent sighting of northern elephant seals in central California was of four individuals on Año Nuevo Island, California, in July 1955 (Radford et al 1965). Sightings were made occasionally on Año Nuevo Island during the remainder of the 1950's (Table 5). A solitary individual was reported on the Farallon Islands in July 1959 (Thoresen 1959).

A birth occurred on Año Nuevo Island in 1961 (Radford et al 1965), and northern elephant seals have bred on the California mainland adjacent to Año Nuevo Island since 1975 (Le Boeuf, pers. comm.).

Rookeries of the Farallon Islands are the most recent to be recolonized by northern elephant seals. A solitary individual was sighted ashore there in July 1959 (Thoresen 1959). The first births occurred in January

Table 5. Censuses of the Central California subpopulation

YEAR	MONTH	LOCATION[1/]		COMMENTS	SOURCE
		ANI	FI		
1955	July	4	-		Radford _et al_ 1965
1956	September	2	-		Radford _et al_ 1965
1958	August	9	-		Radford _et al_ 1965
1959	July	-	1		Thoresen 1959
1960	October	35	-		Radford _et al_ 1965
	December	35	-		Radford _et al_ 1965
1961	March	24	-	First pup on ANI	Radford _et al_ 1965
	May	86	-	All immatures	Radford _et al_ 1965
	November	51	-		Radford _et al_ 1965
1965	June	363	-		Carlisle and Alpin 1966
1969	June	172	-		Frey and Alpin 1970
1970	May	-	60		Le Boeuf _et al_ 1974
	June	85	-		Carlisle and Alpin 1970
1971	February	600	-		Le Boeuf _et al_ 1974
	May	1000	38		Le Boeuf _et al_ 1974

Table 5 (Continued)

YEAR	MONTH	LOCATION[1/]		COMMENTS	SOURCE
		ANI	FI		
1972	January	-	-	First pup born on FI	Huber, pers. comm.
1972	February	700	-		Le Boeuf _et al_ 1974
	May	1020	105		Le Boeuf _et al_ 1974
1973	May		189		Le Boeuf _et al_ 1974
	January - February	1036			Le Boeuf 1974

[1/] ANI = Año Nuevo Island, FI = Farallon Islands

1972 (H. Huber, Point Reyes Bird Observatory, Bolinas, California, pers. comm.).

Age and Sex Structure

A considerable amount of effort has been devoted to tagging newborn elephant seals on rookeries throughout the species range. Many of the pups were sexed at the time of tagging. These records, which provide good data on the sex ratio at birth, are summarized by subpopulation in Table 6. Although not tested statistically, it would appear that, in all subpopulations, the sex ratio at birth does not deviate from 50:50 (Le Boeuf et al 1972). In addition, five age and sex categories, identifiable under optimal field conditions, have been described (Le Boeuf et al 1974): 1) pups, 2) juveniles or immatures, 3) adult females, 4) subadult males, and 5) adult males. Pups are animals less than four months old found on the rookeries between January and April. Juveniles are ages 1-4 years ashore during the spring peak. It is extremely difficult to sex immature animals. The adult females are ashore during the winter peak and are normally 3 or more years old, although some may give birth at age two years. Subadult males are 5-8 years old, whereas the adult males are 9 years or older. These age categories are not apparent throughout the year. Adult females, juveniles of both sexes, and any pups ashore have not been distinguished during the spring peak (Le Boeuf et al 1974, Odell 1974). More typically, both the ratios of adults to pups and adult males to adult females are recorded in the winter peak, with only three categories recognized: 1) pups, 2) adult females, and 3) adult males. Classification of pups and adult females is identical

Table 6. Sex ratio of newborn pups by subpopulation and rookery (After Le Boeuf *et al* 1974).

SUBPOPULATION	ROOKERY	SAMPLE SIZE	PERCENT	
			Males	Females
Baja California				
	Guadalupe Islands	1,415	49.5	51.5
	San Benito Islands and Cedros Islands	106	51.9	48.1
Channel Islands				
	San Miguel Island	2,159	49.0	51.0
	San Nicolas Island	395	50.3	49.7
Central California				
	Año Nuevo Island	540	49.4	50.6

to that given above. The adult male category includes both subadults and adults; or all males over 5 years.

At least three factors hinder accurate analysis of population structure from these ratios. First, females come ashore to pup in their third year and are classified as adults at this time. In contrast, males function as immatures until they are at least five years of age. Thus, a higher proportion of the female segment of the population is classified as adult. Secondly, long term observations have shown marked differences between sexes in the maximum number of adults ashore per day as a percentage of the total number of adults using the rookery. A maximum of 89% of the females and 52% of the males using the main rookery on Año Nuevo Island are ashore each day (calculated from data in Le Boeuf 1972). Similarly, a maximum of 89% of the females utilizing the rookeries on San Nicolas Island are ashore at one time (calculated from data in Odell, 1972). Thirdly, both ratios are dynamic throughout the winter peak. The ratio of adult males: adult females varies, as each group tends to come ashore at different times, the females arriving later than the males and departing sooner. The ratio of adults to pups changes continuously; initially as pupping progresses, and then as adults return to sea. These changes are well exemplified by the figures for adult-pup ratios on San Nicolas Island between 26 January and 8 February 1972 (Table 7).

Baja California subpopulation -- Data from the Baja California islands are limited (Table 7). Counts in 1950 (Bartholomew 1952) and 1965 (Rice et al 1965) provide very similar adult to pup ratios. The more recent figures given by Kenyon (1973) show the highest proportion of pups

Table 7. Observed adult sex ratio and ratio of adults to pups on selected rookeries.

DATE	LOCATION	ADULTS Male:Female	ALL ADULTS:PUPS	SOURCE
		BAJA CALIFORNIA SUBPOPULATION		
January - February 1950	Guadalupe Island and San Benito Islands	1:2	1:056	Bartholomew 1952
January 1965	Guadalupe Island and San Benito Islands	-	1:053	Rice *et al* 1965
February 1973	Guadalupe Island	1:1.54	1:1.12	Kenyon 1973
		CHANNEL ISLAND SUBPOPULATION		
11 February 1958	San Miguel	1:4.09	1:0.43	Bartholomew and Boolootian 1960
8 February 1964	San Miguel	1:3.02	1:0.71	Odell 1971
26 January 1972	San Miguel	1:3.09	1:0.47	DeLong pers. comm.
3 February 1972	San Miguel	1:3.44	1:0.66	Odell *et al* 1976[1/]
8 February 1972	San Miguel	1:2.83	1:1	Odell *et al* 1976[1/]
23 January 1959	San Nicolas	1:4.09	1:0.43	Bartholomew and Boolootian 1960
9 February 1964	San Nicolas	1:8.15	1:0.66	Odell 1971
26 January 1972	San Nicolas	1:3.09	1:0.47	Odell *et al*
8 February 1972	San Nicolas	1:2.96	1:0.98	Odell *et al* 1976[1/]
8 February 1972	Santa Barbara	1:10.0	1:0.60	Odell *et al* 1976[1/]

Table 7 (Continued)

DATE	LOCATION	ADULTS Male:Female	ALL ADULTS: PUPS	SOURCE
		CENTRAL CALIFORNIA SUBPOPULATION		
January - February 1968	Año Nuevo	1:2.8	-	Le Boeuf 1972
January - February 1969	Año Nuevo	1:3.7	-	Le Boeuf 1972
January - February 1970	Año Nuevo	1:4.6	-	Le Boeuf 1972
January - February 1973	Año Nuevo	1:2.6	1:0.59	Le Boeuf 1974

1/ See text footnote number one.

to adults ever reported. Such a high ratio in a monoparous species strongly suggests the count was made after a significant number of adults, probably mostly females, had returned to sea. This probability nullifies Kenyon's (1973) adult sex ratio. The only other estimate of the adult sex ratio was taken in 1950 by Bartholomew (1952). In light of the possible biases discussed above, it can only be summarized that there are about twice as many females as males in the breeding segment of the population.

Channel Island subpopulation -- Counts on the Channel Islands, which have been rather sporadic (Table 7), tend to emphasize the dynamic nature of short-term changes in proportions of each segment ashore during the winter peak rather than provide a meaningful estimate of population structure. It may be significant that all figures from the Channel Islands subpopulation show a higher proportion of females than does the single ratio for the Baja California subpopulation.

The figures provide an opportunity for a comparison of sex ratios and adult to pup ratios over time between rookeries in close proximity. For example, in February 1964, San Miguel Island attracted a considerably lower proportion of females, which had apparently borne more pups, than did San Nicolas Island (Odell 1971). In February 1972, these ratios show the proportions of individuals in the winter peak on both islands to be almost identical (Odell et al 1976[1/]). Simultaneously, Santa Barbara Island, reestablished as a rookery only six years earlier (Odell 1971), hosted remarkably more females than males. This highly disproportionate sex ratio is attributed to the physical nature of the Santa Barbara Island beaches, which enables socially dominant males to prevent subordinates from landing (Odell *et al* 1976[1/]).

Central California subpopulation -- The most complete figures for an adult sex ratio on any northern elephant seal rookery are those for Ano Nuevo Island (Table 7). The figures, which are cumulative for the entire winter peak (Le Boeuf 1972, 1974), show a continuous increase in the relative proportion of females utilizing Año Nuevo Island between 1968 and 1970. However, due to an increase in the number of males ashore, the adult sex ratio for 1973 approximates that of 1968. This represents a considerable variation in the proportion of females in the breeding population between seven and twelve years after reestablishment of the rookery. Its possible significance is not understood.

The ratio of adults to pups given for 1973 (Le Boeuf 1974) falls well within the range of counts for other rookeries.

Population Estimates

A review of the annual cycle shows that not all cohorts of northern elephant seals are ashore simultaneously. A considerable portion of the entire population comes ashore during two periods. Adults of both sexes and pups constitute the winter peak. The spring peak consists of both sexes of adults and immatures. Methods have been derived to estimate the total population from censuses of that portion of the population ashore. All censuses have been total counts.

Apparently, the estimates of minimum population size given by Anthony (1924) and Hanna (1925) (Table 3) are no more than educated guesses. The first population estimators were devised by Bartholomew and Hubbs (1960). Their methods are based on censuses of either the spring or winter peaks. The spring census figure is increased by 10% of its size to correct for missed animals, and by an additional 15% to account for adult males away at sea; or

$$\text{Total population size} = Y + .10Y + .15Y$$

where Y is the spring peak census figure. Similarly, a winter census figure is increased by 20% to account for immatures away at sea; or,

$$\text{Total population size} = X + .20X$$

where X is the winter peak census figure. This latter method was followed by Rice et al (1965). No justification is offered for fixing the correction factors at the levels used (Bartholomew and Hubbs 1960).

A method of estimating the size of a rookery from counts of the number of pups has been proposed. It is suggested that the ratio of all age classes, other than pups to pups, is approximately 3:1 (Peterson and Le Boeuf 1969). This method has been used to estimate the number of northern elephant seals utilizing San Miguel Island (Johnson and DeLong 1976[2/]).

Other workers (Odell et al 1976[1/]) note that the total population size may be obtained by tallying counts of adults, immatures, and pups. However, good estimates of the number of immatures ashore during the spring peak are not readily obtainable, as they are almost indistinguishable from adult females. Censuses from San Nicolas Island (Odell 1971) and Ano Nuevo Island (Le Boeuf et al 1974) suggest that there are approximately 2.5 times more immatures than adults on these islands (Odell et al 1976[1/]).

2/. Johnson, A.M., R.L. DeLong. 1976. Increase in the northern elephant seal population on San Miguel Island, California. Unpubl. manuscr. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Northwest Fish. Center, Seattle, Wash. 10 p.

However, as both islands may be receiving considerable numbers of immature immigrants each year (Odell 1972, B.J. Le Boeuf, Div. of Natural Sciences, University of California, Santa Cruz, California, pers. comm.), they may not be typical of all rookeries. Comparison of the Guadalupe Island 1970 spring peak count to the 1969 winter peak count, corrected for pups (Table 3), suggests that numbers of breeding adults may closely approximate numbers of immatures.

The numbers of immatures utilizing a rookery may vary considerably between subpopulations and islands. Therefore, direct estimates of immature numbers, and thereby total population size, are not possible until data comparable to that gathered on San Nicolas Island (Odell 1974) and Año Nuevo Island (Le Boeuf _et al_ 1974) are available for other rookeries, particularly those on San Miguel Island, Guadalupe Island, and San Benito Islands. As a result, efforts are being directed towards obtaining good estimates of the number of pups and breeding adults in each subpopulation. Gross estimates of total numbers may be obtained by using the ratio 3:1 for all other age classes to pups (Peterson and Le Boeuf 1969). Numbers of immatures may then be approximated from the above figures.

The following cohort specific method has been devised to estimate the number of pups, breeding adults of each sex, and immatures in each subpopulation. The calculations used are as follows: 1) From a winter census figure, the proportion of pups is calculated from an adult:pup ratio; 2) an adult sex ratio is then used in calculating actual numbers of adult males and females; 3) each of these figures is corrected to account for sex specific differences in the percentage of adults ashore (at least 48% of the males and 11% of the females utilizing a rookery are absent at any given time calculated from data in Le Boeuf 1972, Odell 1972). Thus, the total number of adult males (m_t) becomes:

$$m_t = m_c/0.52$$

where m_c is the number of males censused or calculated from the ratio of males to females applied to the total census and 0.52 is the decimal equivalent that m_c represents of the total (m_t).

Similarly, the total number of adult females becomes:

$$F_t = F_c/0.89$$

where F_c is the number of females censused or calculated from the total census and 0.89 is the decimal equivalent that F_c represents of the total (F_t). 4) the total population size is obtained by multiplying the number of pups by four; and 5) the number of immatures is obtained by subtracting numbers of adults and pups from the total. An example of the cohort specific method using figures for the Baja California subpopulation in 1950 follows:

a) the census figure is 5,400 animals and the adult:pup ratio is 1:0.56. Thus

$$\frac{.56}{1.56} = \frac{X}{5410} = 1{,}942 \text{ Pups.}$$

b) the sex ratio among the 3,468 adults is 1:2 so there are 1,156 males and 2,312 females.

c) correcting for the percentage of adults ashore:

$$m_t = 1156/0.52 = 2223$$

$$F_t = 2312/0.89 = 2598$$

d) obtaining total population size

4 x 1,942 = 7768

e) calculating number of immatures

7768 - (1,942 + 2223 + 2598) = 1005

Information necessary for cohort specific estimates of population size are summarized in Table 8. Estimates are made of the size of the Baja California subpopulation in 1950, 1965, and 1969; and of the Channel Island subpopulation in 1958, 1964, and 1972. Data for the Baja California subpopulation are somewhat scanty. The only published adult sex ratio was taken in 1950 (Bartholomew 1952). By necessity, this figure was used in all cohort specific estimates of numbers in the Baja California subpopulation. Similarly, the ratio of adults to pups taken in 1965 (Rice et al 1965) is used for the 1969 estimate. Finally, the census figure for February 1969 is obtained by extrapolation. The actual count in February 1969 was of only a portion of the subpopulation as animals on San Benito Islands were not included (Hubbs, pers. comm.) (Table 3). Northern elephant seals were censused on Guadalupe Island and the San Benito Islands in January 1965 (Rice et al 1965) (Table 3). It is assumed that the ratio of northern elephant seals on Guadalupe Island in January 1965 and February 1969 is similar to that for San Benito Islands for the same time periods. Accordingly, it is possible to derive an estimate of northern elephant seal numbers on San Benito Islands in February 1969. This figure may then be added to the tally for Guadalupe Island to provide a census figure for the Baja California subpopulation.

Estimates of the size of the Channel Island subpopulation may be simplified by applying the ratio of adults to pups and adult sex ratio from

Table 8. Census figures, ratios of adults to pups, and adult sex ratios used in estimating population size for the northern elephant seal.

SUBPOPULATION	YEAR	CENSUS FIGURE	ALL ADULTS:PUPS	ADULT Males:Females	SOURCE
Baja California	1950	5,410	1:0.56	1:2	Bartholomew 1952
Baja California	1965	13,300	1:0.53	-	Rice _et al_ 1965
Baja California	1969	19,600	-	-	Hubbs, pers. comm.
Channel Islands	1958	615	1:0.43	1:4.09	Bartholomew and Boolootian 1960
Channel Islands	1964	2,160	1:0.71	1:3.02	Odell 1971
Channel Islands	1972	5,160	1:0.66	1:2.83	Odell _et al_ 1976[1/]

1/ See text footnote number one.

San Miguel Island to the entire subpopulation. Three factors justify this simplification: 1) a high proportion of the subpopulation utilizes San Miguel (Table 4), 2) the ratios for San Miguel and San Nicolas rookeries are quite similar, and 3) the more divergent ratios from Santa Barbara Island (Table 7) are for a very small portion of the entire subpopulation (Table 4).

The size of the entire northern elephant seal population may be calculated by totalling numbers in each subpopulation at approximately the same time. Thus, a mid-1960's total is obtained by summing the 1964 estimate for the Channel Islands subpopulation with the 1965 Baja California subpopulation estimate, and an approximation of the central California subpopulation. An early 1970's estimate of the entire population, which covers a slightly wider time span, is obtained by summing estimates for the Baja California subpopulation in 1969, the Channel Island subpopulation in 1972, and total counts of the central California subpopulation (Le Boeuf et al 1973, Le Boeuf 1974).

For comparative purposes, the winter peak population estimator devised by Bartholomew and Hubbs (1960) is applied to the Baja California census figures for 1950 and 1969, and the Channel Islands census figure for 1972 (Table 8). These subpopulation figures may also be combined to give an independent estimate of total population size.

Estimates of the size of the northern elephant seal population by the methods described by Bartholomew and Hubbs (1960) are summarized in Table 9. Estimates obtained by the cohort specific method described in this paper are presented in Table 10. In all comparable cases, the latter method provides estimates higher than those obtained by the

Table 9. Size of the northern elephant seal population by subpopulations from estimators devised by Bartholomew and Hubbs (1960).

YEAR	SUBPOPULATION	NUMBER	PERCENT	SOURCE
1950	Baja California	6,600	99	This paper.
	Channel Island	100	1	This paper.
	Central California	0	-	This paper.
	TOTAL	6,700	-	
1957	Baja California	12,650	95	Bartholomew and Hubbs 1960
	Channel Islands	600	5	Bartholomew and Hubbs 1960
	Central California	0	-	Bartholomew and Hubbs 1960
	TOTAL	13,250	-	
1960	Baja California	14,400	96	Bartholomew and Hubbs 1960
	Channel Islands	600	4	Bartholomew and Hubbs 1960
	Central California	0	-	Bartholomew and Hubbs 1960
	TOTAL	15,000	-	
1965	Baja California	13,295	94	Rice et al 1965
	Channel Islands	580	4	Rice et al 1965
	Central California	195	2	Rice et al 1965
	TOTAL	14,070	-	
Early 1970's	Baja California	23,520	75	This paper.
	Channel Islands	6,190	20	This paper.
	Central California	1,720	5	Le Boeuf 1974
	TOTAL	31,430	-	

Table 10. Cohort specific estimates of the size of northern elephant seal subpopulations for 1950, 1958, the mid-1960's, and early 1970's

SUBPOPULATION	ADULT				IMMATURES		PUPS		TOTAL	
	Male		Female							
	No.	%	No.	%	No.	%	No.	%	No.	%
					1950					
Baja California	2,223	29	2,598	33	1,007	13	1,942	25	7,770	99
Channel Islands	-	-	-	-	-	-	-	-	100	1
Central California	-		0		0		0		0	
TOTAL									7,870	100
					1958					
Baja California	-		-		-		-		-	
Channel Islands	165	22	390	53	0	0	185	25	740	
Central California	-		-		-		-		-	
					Mid-1960's					
Baja California	5,573	30	6,511	35	1,735	9	4,607	26	18,428	83
Channel Islands	605	17	1,066	30	1,022	28	897	25	3,590	17
Central California	-		-		-		-		100	-
TOTAL	6,178	26	7,977	33	2,799	16	5,504	25	22,120	100
					Early 1970's					
Baja California	8,210	30	9,595	35	2,565	10	6,790	25	27,160	73
Channel Islands	1,560	19	2,580	31	2,010	25	2,050	25	8,200	22

Table 10 (Continued)

SUBPOPULATION	ADULT				IMMATURES		PUPS		TOTAL	
	Male		Female							
	No.	%	No.	%	No.	%	No.	%	No.	%
Central California	200	12	525	31	565	32	430	25	1,720	5
TOTAL	9,970	27	12,700	34	5,140	14	9,270	25	37,080	100

former. Few independent population data are available for comparison to the estimates. However, recently published results of censuses of breeding females taken on a number of rookeries from 1969 to 1974 (Le Boeuf and Petrinovich 1974) do permit at least partial comparison of the cohort specific estimates. The estimated figure of 9,475 for the Baja California subpopulation is higher than the census figure of 8,400 for Guadalupe and San Benito Islands (Le Boeuf and Petrinovich 1974) whereas the estimate of 2,885 compares favorably with the count of 2,800 breeding females on San Miguel and San Nicolas Islands (Le Boeuf and Petrinovich 1974).

Population Growth, Numbers, and Trends

Estimates have not been made of the size of the northern elephant seal population prior to 1800. Commercial exploitation, from the early 1800's until about 1860 and again briefly in the 1880's (Townsend 1885), decimated numbers. Only 100 northern elephant seals were estimated to be living by about 1900 (Bartholomew and Hubbs 1960). Numbers have increased continuously since that time.

Baja California subpopulation -- By 1892, Guadalupe Island was the only hauling ground used by northern elephant seals. Numbers sighted on the island have increased steadily from a low of four in 1904 (Townsend 1912) (Table 3). A census in 1922 suggested a total population of "no less than" 1,000 individuals (Hanna 1925). A count the following year suggested to Anthony (1924) that a population estimate with the figure of 100 individuals for 1900 (Bartholomew and Hubbs 1960) implies a ten-fold increase over 20 years, which is unlikely. It is probable that either the 1900 population estimate is too low, or the 1920's estimates are too high. The former appears to be more likely.

Few counts were made from the late 1920's until the late 1940's (Table 3). The first count over a winter peak was made in 1950 (Bartholomew 1952) (Table 3). Over 5,400 animals were ashore on Guadalupe Island and the San Benito Islands. The method of Bartholomew and Hubbs (1960) and the cohort specific estimator set the total population number at 6,600 (Table 9) and 7,800 (Table 10), respectively. This represents a five to six fold increase in numbers over 25 years or a doubling in the size of the population every five years.

The first series of counts reflecting seasonal variation in abundance on breeding rookeries were taken of Guadalupe Island in 1957 (Bartholomew and Hubbs 1960) (Table 3). Over 5,000 animals were ashore during the winter peak. The count for April, close to the spring peak, exceeded 9,100. On the basis of these counts the Baja California subpopulation was estimated to number 12,650 (Bartholomew and Hubbs 1960) (Table 8). A count in January, 1960, just over three years later, showed a winter peak of over 11,000 on Guadalupe Island (Bartholomew and Hubbs 1960). The subpopulation was estimated to have increased to 14,400 animals (Bartholomew and Hubbs 1960). The next census was undertaken during January 1965 (Rice et al 1965). The winter peak count of 10,400 elephant seals on Guadalupe Island suggest a subpopulation comparable in size to that of 1960. An additional 2,800 animals were counted on the San Benito Islands (Rice et al 1965). An estimated subpopulation size of 13,295 by use of the estimator of Bartholomew and Hubbs (1960) is in reasonably close agreement with the 1960 estimate of 14,400. The cohort specific estimator sets the

1965 subpopulation size at 19,100 (Table 10).

Censuses of northern elephant seals in the Baja California subpopulation have become more sporadic in the last decade (Table 3). Indeed, systematic censuses within a single year, necessary to determine seasonal peaks in numbers, have not been undertaken since 1957. However, censuses made in consecutive years do provide counts approximating the winter and spring peaks on two occasions. As annual changes in the size of the winter peak (breeding population and pups) and spring peak (adults and immatures) are likely to be relatively slow, figures for consecutive years have been used together. Thus, the censuses from January, 1965 and April, 1966 (Table 3), are treated as the 1965-1966 winter and spring peak, respectively. Similarly, the censuses for February, 1969 and April, 1970 (Table 3) are treated as the 1969-1970 winter and spring peak. Accordingly, the 1965-1966 winter peak on Guadalupe Island contained some 10,500 adults and pups (Rice et al 1965), whereas over 15,000 adults and immatures were ashore during the spring peak (Hubbs, pers. comm.). In contrast, the 1969-1970 winter peak is some 15,300 strong (Hubbs, pers. comm.) and the spring peak of adults and immatures has dropped to approximately 9,100 (Bonnell and Pierson 1970).

The 1969 winter peak of 15,300 animals of Guadalupe Island (Table 3) may be extrapolated to a winter peak of 19,600 for the entire Baja California subpopulation. The method of Bartholomew and Hubbs (1960), and the cohort specific estimator set the subpopulation size at 23,520 (Table 9) and 27,160 (Table 10), respectively. Thus, the Baja California subpopulation has increased continuously since 1900 and entered the 1970's at its highest level in the century (Fig. 6). However, the transition of maximum numbers ashore from the winter peak to the spring peak may be indicative of an influx of a substantial number of 1965 - 1966 immatures into the 1969 - 1970 adult segment of the population without adequate survival of pups to replace the immatures. If this situation is indeed true, it may be assumed that the rate of growth of the subpopulation will decline.

Channel Islands subpopulation -- Sightings of northern elephant seals on the Channel Islands were sporadic from the time of their return in the 1920's through the 1940's (Table 4). All available figures show that numbers have increased continuously. The subpopulation, estimated to number 600 in 1957 (Bartholomew and Hubbs 1960), was revised to between 412 and 683 animals the following year (Bartholomew and Boolootian 1960). The cohort specific method provides a slightly higher estimate of 740 in 1958 (Table 10). A subpopulation estimate of 600 was used again in 1960 (Bartholomew and Hubbs 1960).

Numbers in the Channel Islands subpopulation increased sharply, and possibly doubled in 1965 (Carlisle 1973). Estimates of 580 in 1965 given by Rice et al (1965) (Table 9) are far below the 2,160 counted by Odell (1971) the same year (Table 7). Based on the latter the cohort specific method gives an estimate for the subpopulation of 3,600 (Table 10). Such an increase could only have resulted from a massive influx of animals from the Baja California subpopulation.

The greatest number ever recorded ashore in the Channel Islands subpopulation was 5,160 in February 1972 (Odell et al 1976[1/]) (Table 4). Population estimates based on this census give figures of 6,190 (Table 9)

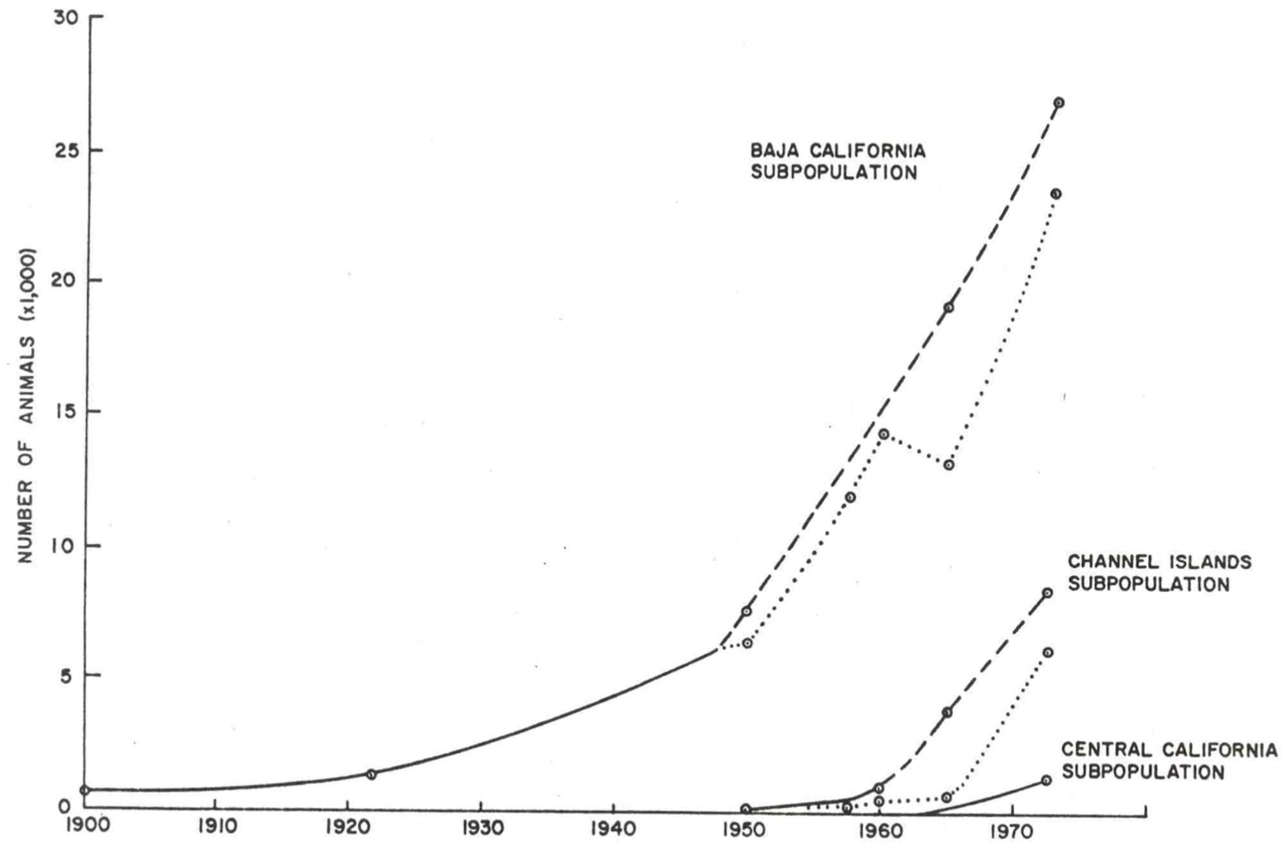

Fig. 6. Increase in numbers of northern elephant seals in each of three subpopulations. Dotted lines are eye-filled to estimates (circled) from method of Bartholomew and Hubbs (1960); dashed lines are eye-filled to cohort specific estimates; solid lines are approximation (1900 - 1960) or total counts (1960 - 1970).

and 8,200 (Table 10) for the method of Bartholomew and Hubbs (1960) and the cohort specific method, respectively. The subpopulation may have continued to increase since 1972. Counts of pups lead to an estimate of 16,000 elephant seals of all age classes on San Miguel Island alone in 1975 (Johnson and DeLong 1976[1/]).

The Channel Island subpopulation has increased continuously since recolonization began in the 1930's. The rate of growth has been accelerated by immigration from the Baja California subpopulation (Le Boeuf, pers. comm.), and all indications are that the population will continue to increase. Large beach areas apparently suitable for elephant seal rookeries remain unoccupied during both the winter and spring peaks (DeLong, pers. comm.). The role that immigration from the Baja California subpopulation will play in further growth of the Channel Islands subpopulation is not known.

Central California subpopulation -- Northern elephant seals were resighted on both Año Nuevo and the Farallon Islands in the 1950's (Thoresen 1959, Radford et al 1965), and numbers have increased continuously due to continued immigration, chiefly from the Channel Islands subpopulation (Le Boeuf, pers. comm.), and establishment of active rookeries. Over 360 northern elephant seals were counted on Año Nuevo Island in June, 1965 (Carlisle and Alpin 1966), and this subpopulation has since been monitored closely through total counts. By May 1972 the summer peak count included over 1,000 individuals (Le Boeuf, pers. comm.); almost a three-fold increase in seven years. The winter peak population increased from 700 in 1972 (Le Boeuf et al 1974) to over 1,030 in 1974 (Le Boeuf 1974) (Table 5).

Numbers of northern elephant seals hauling out on the Farallon Islands jumped from a solitary individual in July 1959 (Thoresen 1959) to 60 in May 1970, and increased to 189 in May 1973 (Le Boeuf et al 1974).

There may be little potential for continued growth in this most northerly subpopulation. Suitable rookery sites are limited on both Año Nuevo Island and the Farallon Islands. All such areas are crowded at present population levels (Le Boeuf, pers. comm.). Elephant seals have bred on the mainland adjacent to Año Nuevo since 1975 (Le Boeuf, pers. comm.), but the extent to which mainland rookeries become established may affect the ultimate size of the central California subpopulation.

Total population -- A summary of estimated subpopulation sizes shows that the entire northern elephant seal population has increased from 6,600 or 7,870 in 1950 to 31,430 or 37,080 in 1970. Both sets of figures represent approximately a five-fold increase in numbers over 20 years, however, the rate of increase has not been equal among subpopulations. The proportion of the total population represented by the Channel Islands subpopulation increased from about one percent in 1950 to 20 - 22 percent in 1970. Simultaneously, the Baja California subpopulation has declined from 99 percent of the total population in 1950 to 73 - 75 percent of the total in 1970. Further growth of the Channel Island subpopulation at a rate faster than that of the Baja California subpopulation will alter the proportion even more.

CRITICAL HABITATS

Critical habitats may be defined as those portions of the biological and physical environment required for the normal needs and survival of a species. The environmental needs of northern elephant seals are known to extend in a narrow ribbon, some 200 miles wide, of coastal waters and islands from central Baja California to southern Alaska. This range may require modification as information on the oceanic movements of females becomes available. Continued access to undisturbed islands appears to be the most critical factor in the species' habitat. Any change in the physical and biological qualities of this region may affect the abundance and distribution of northern elephant seals.

Long-term environmental changes -- In addition to a increase in the number of northern elephant seals, there have been significant shifts in numbers and distribution of other pinniped populations along the coast of California. The number of northern sea lions have dwindled from some 2,000 in 1938 to approximately 50 (R.L. DeLong, Natl. Mar. Fish. Serv. Northwest and Alaska Fish. Center, Seattle, WA. 98115, pers. comm.), whereas the northern fur seal has recently become established on San Miguel Island (Peterson *et al* 1968). Concurrently, the California sea lion (*Zalophus californianus*) population has increased tremendously since the 1930's (Bartholomew and Boolootian 1960).

Long-term environmental changes may have a severe impact on northern elephant seals. Electrophoretic studies have shown that the species exhibits no genetic heterozygosity (Bonnell and Selander 1974). Thus, the ability of northern elephant seals to adapt to even the slightest environmental change may be far below that of most free-ranging species of pinnipeds.

Environmental pollutants -- The proximity of northern elephant seal rookeries on the Channel Islands to oil drilling operations in the Santa Barbara Channel continuously expose them to oil spills. An oil spill on January 30, 1969, and subsequent contamination of the San Miguel Island coastline provided an opportunity to examine the effect of oil pollution on northern elephant seals.

Short term adverse effects of the oil contamination were not found. Few sick or dead elephant seals were found ashore. No petroleum traces were present in tissues taken from two dead individuals or in blood samples from live animals (Simpson 1970, Simpson and Gilmartin 1970). The likelihood of finding oil residues in animals, other than those ingesting oil, has been questioned (Le Boeuf 1971).

Long term effects of oil contamination were followed by marking groups of contaminated and non-contaminated weaned pups (Le Boeuf 1971). Resightings were followed during the 15 months from April 1969 to June 1970. The pattern of resightings suggests that oil contamination had no effect on the health of weaned pups (Le Boeuf 1971). It must be stressed however, that contamination of rookeries at other times of the year, particularly when pups are suckling, may directly influence population numbers through direct mortality of pups.

Recent studies have shown that tissues of northern elephant seals contain unusually high levels of mercury (Le Boeuf, pers. comm.), however the implications of these findings are unknown.

Human disturbance -- Bartholomew (1952) noted that, "on the various beaches on Guadalupe Island where the animals were breeding, no amount of human activity or disturbance would cause any of the adult animals to enter the water or retreat along the beach." More recent observations suggest that, although they do not flee immediately, northern elephant seals do tend to desert areas frequented by man. Thus, Kenyon (1973[3/]) noted that the northern end of a beach on Guadalupe Island adjacent to a fishing camp was almost deserted, whereas elephant seals were concentrated as the southern edge of the beach. Similarly, elephant seals on San Miguel Island have been observed to abandon the beach used for landing supplies (DeLong, pers. comm.) In addition, the small mainland rookery adjacent to Año Nuevo Island attracts considerable numbers of sightseers, but their effect on the breeding animals is not known. It seems reasonable, however, that more animals might be expected to utilize the area if disturbance was reduced (Le Boeuf, pers. comm.).

Conservation measures -- Northern elephant seals are but one species living in the biotic communities of the Pacific coast of North America. Conservation measures directed at preservation of communities will have a direct effect on northern elephant seals.

The species has long been protected in Mexico and Guadalupe Island has been a nature preserve since early this century. The impact of utilization of the island by small numbers of fishermen (Kenyon 1973[3/])

3/. Kenyon, K.W. 1973. Unpubl. manuscr. Human disturbance of marine birds and mammals in wilderness areas of Baja California, Mexico, 10-17 February 1973. U.S. Fish Wildl. Serv., Bur. Sports Fish. Fildl., Mar. Mammal Substation, Seattle, Wash. 16 p.

emphasizes the need for strict control of human access.

The largest northern elephant seal rookery in the United States is on San Miguel Island. At present, administration for the island is being transferred from the U. S. Navy to the U. S. National Park Service. The U. S. Navy will retain title to the island, and the U. S. National Marine Fisheries Service will retain jurisdiction over all pinnipeds in the Channel Islands.

CONCLUSIONS

All available information suggests the northern elephant seal is well on its way to re-establishment throughout its original range. The species utilizes the waters and islands off the North American Pacific coastline from central Baja California to southern Alaska. Rookeries are now occupied from San Benito Islands, Baja California, to the Farallon Islands, California. The population has increased from an estimated 100 animals at the turn of the century to some 31,500 to 37,000 in the early 1970's. Numbers on the Channel Islands may continue to increase. Present and proposed conservation measures are likely to ensure the continued survival of the species.

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