SOUTHWEST FISHERIES SCIENCE CENTER

NATIONAL MARINE FISHERIES SERVICE
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USING LARGE FORMAT VERTICAL AERIAL PHOTOGRAPHY TO CENSUS NORTHERN ELEPHANT SEALS *(Mirounga angustirostris)* AT SAN MIGUEL, SAN NICOLAS, AND SANTA ROSA ISLANDS, CALIFORNIA

By

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ADMINISTRATIVE REPORT LJ-92-20

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ABSTRACT

Large format (126 mm and 228 mm) vertical aerial photographs were used to census northern elephant seals (Mirounga angustirostris) at San Miguel Island from 1985 to 1991, at San Nicolas Island from 1988 to 1991, and at Santa Rosa Island from 1990 to 1991. Analysis of replicate counts of elephant seals from 126 mm format aerial color photographs indicates that counts of pups are extremely precise with coefficients of variation ranging from 0.0064 to 0.0152. Numbers of elephant seals at San Miguel Island and Santa Rosa Island have increased during 1985 to 1991, but at San Nicolas Island they were relatively constant from 1989 to 1991.

INTRODUCTION

The largest breeding aggregations of northern elephant seals (Mirounga angustirostris) in the United States occur at San Miguel Island (SMI) and San Nicolas Island (SNI), located off the coast of southern California, USA (Fig. 1). Other large breeding colonies are found along Baja California, Mexico at Guadalupe Island and Isla San Benito (Cooper and Stewart 1983). Northern elephant seals give birth and breed during the winter from late December through February. Counts of pups taken during the breeding season at SMI, SNI and other small rookeries in the U.S are used together with the dynamic response method for monitoring the status of the United States population (Goodman 1988, Gerrodette 1988, Boveng et al. 1988).

Aerial photography has been used for counting various pinniped species found on remote islands or otherwise inaccessible areas (Bartholomew and Boolotian 1960, Ripley et al. 1962, Carlisle and Aplin 1966, Odell 1971, Braham 1974, Lavigne 1976, Lavigne et al. 1975, 1980, Mate 1977, Shaughnessy 1987, Antonelis et al. 1981, Taylor 1982, Hanan et al. 1985, 1986a, 1986b, Hiby et al. 1988). These aerial photographic surveys have used 35 mm to 228 mm format cameras that were hand-held or mounted in the aircraft.

In this report we introduce equipment and procedures used to

count northern elephant seals from large format (126 mm and 228 mm) vertical photographs and present counts for SMI (1985-1991), SNI (1988-1991), and Santa Rosa Island (SRI; 1990-1991). We will also compare the results of the two commonly used techniques for estimating elephant seal pup production (i.e. peak adult-females-plus-weaned-pups versus late season pup counts). The count of adult-females-plus-weaned-pups during the peak of the breeding season is a useful alternative to late season counts of pups or of pup production when no late season counts of pups are made and because pup mortality prior to the late season count of pups would yield an erroneous figure of total pup production (specially in years of high pup mortality).

METHODS

A vertically-mounted 228 mm format RC-10 camera was used on a Cessna 207 aircraft to photograph northern elephant seals in 1985 and 1986. Kodak Aerochrome 2448 color transparency film was used. Photographs were taken with 66% overlap between adjacent frames. The aircraft was flown at an altitude between 261 and 290 meters, and a ground speed of 90 kts. The exposure setting of the RC-10 camera is unknown.

Resolution of the aerial photographs was improved when a 126 mm format KA-45A military reconnaissance camera was used from

1987 to 1991. The forward image motion compensation feature of this camera eliminated loss in resolution associated with the forward motion of the aircraft. The camera was mounted vertically in a twin-engine Partenavia P-68 aircraft that was flown at altitudes between 244 and 366 meters and at a ground speed of 110 kts. The camera was set to take photographs with 66% overlap between adjacent frames. Kodak Aerochrome 2448 color transparency film was used. When a second KA-45A camera was used, fine-grained black and white photographs were taken with Kodak Panatomic-X Aerocon 3412 film. The black and white photographs are used for measuring seals and determining the area of breeding beaches and the color film is used mainly for counting seals.

The KA-45A was set at an aperture of f/4.0 in 1987 and f/5.6 from 1988 to 1991. Depending on light conditions, a shutter speed between 1/500 and 1/1200 second was used for both films. A haze filter was used on the camera equipped with color film.

We conducted two survey flights each year, except 1987 when logistical problems were experienced (Table 1). The first flight was scheduled to occur near the peak female haul-out period (last week in January). Photographs from this flight document the size and distribution of the rookeries, and the structure of the breeding groups. At the time of this flight, nearly all pregnant females are ashore and 85-90% of the pups have been born (Stewart

and Yochem 1984). Because those females that have arrived early and departed prior to the flight are represented by their weaned pups, the count of females plus weaned pups from this survey provides an excellent estimate of total pup production.

The second flight was conducted to capture late season adults and peak number of pups (third week in February). The difference between the peak (adult-females-plus-weaned-pups) and late season pup production estimates can be used to monitor gross changes in pup mortality between the two flights.

Photographs of northern elephant seals were taken at SMI, SNI, and SRI. At SMI the southern shoreline from Cardwell Point to Point Bennett was photographed from 1985 to 1991, other sections of the island were photographed in 1988-1991 (Fig. 2); visual counts of non-photographed areas were made on 1988 and 1989 flights. At SNI the southern shoreline was photographed from the east end Sand Spit to Vizcaino Point in 1988-1991, other sections were photographed or visually examined in 1989-1991 (Fig. 3). At SRI the southwestern shoreline from the western end of the island at Sandy Point to Bee Canyon was photographed in 1990 and 1991.

Total, or near total (missed areas estimated to have trivial number of seals relative to the total count), photographic coverage of all rookeries was achieved for all islands in all

years we surveyed, except at SMI in 1987. In 1985 and 1986 the northern coastline of SMI was not surveyed visually or photographed. At SMI we missed the entire beach at Cardwell Point, and portions of coastline east of Crook Point in 1987. Near total coverage was achieved in 1988, but we missed a small portion west of Crook Point and between Crook and Cardwell Points on the first flight and small portions of Cardwell Point on both flights. From 1989 to 1991 no rookeries or haulouts were missed at SMI. The rookeries at SNI and SRI had either total coverage or near total coverage for all years of the study.

Elephant seals were counted from color photographs using a light table equipped with 0.7-7X zoom binocular microscope with a 10X ocular. A clear piece of acetate plastic was anchored over selected photographs. The seals in different sex/age classes were then marked with different colored pens as they were counted with a hand counter. Pups that were decomposed, in an abnormal position, or tended by a gull were classified as dead pups, marked on the acetate, and counted after all other categories were counted. For this report we provide our peak-season counts of live pups, dead pups, adult-females-plus-weaned-pups, and adult males, and late season counts of live pups and dead pups. Linear regression analysis was used to test the hypothesis that there is no difference between counts of late season pups and peak season adult-females-plus-weaned-pups, and between peak season adult males (Program QUATRO PRO, Borland International).

Replicate counts from the 126 mm format photographs of elephant seals at SMI were made for 1988 and 1989 to examine precision of counts. Three counts were made by two persons for 1988 and four counts were made by three persons for 1989. We used the coefficient of variation of replicate counts to compare precision between years or groups of seals (Program STATVIEW, Abacus Concepts).

SMI and SNI were divided into areas (Fig. 2 and 3) to document colonization and distribution of breeding areas. We used the same areas at SMI as Stewart (1989) with the exception that the northern coastline was divided into three areas; at SNI we divided the southern coastline into three segments and kept the northern coastline as one segment. At SRI we did not assign area codes because the population of elephant seals occurs in one small area along the southern shore of the western end of the island at Sandy Point.

RESULTS

Replicate counts of elephant seals from 126 mm format aerial color photographs were similar for all categories of seals (Table 2). The variability between replicate counts for live pups, adult-females-plus-weaned-pups, and adult males was very low (Coefficients of Variation [CV] ranged from 0.0032 to 0.0223);

but we found that counts of dead pups were much more variable (CV's ranged from 0.0856 to 0.2117; Table 3).

Counts for all categories of elephant seals at SMI increased during the seven year aerial photo survey period (Table 4 and Fig. 4). The number of pups counted at SMI increased about 36% from 1985 to 1991. A slight downward trend in the number of elephant seals at Point Bennett (Area D; Fig. 5) occurred in conjunction with an increase in numbers from Crook to Cardwell Points (Area A; Fig. 5). At nearby SRI the number of pups counted increased from 23 in 1990 to 86 in 1991 (Table 5). The count of dead pups ranged from 1.2% to 1.6% of the total count of pups at SMI during 1988 through 1991 (Table 4).

At SNI the late-season count of elephant seal pups in 1991 increased 45% from 1989, but trends were not significant (Table 6 and Fig. 4). Dead pups accounted for 1.0% to 1.5% of the total pup count from 1988 through 1991 (Table 6).

Late-season counts of pups were consistently 3% to 9% lower than the count of peak-season adult-females-plus-weaned-pups (Fig. 4). Late-season counts of pups were positively correlated with peak-season counts of adult-females-plus-weaned-pups at SMI ($r^2=0.985$) and at SNI ($r^2=0.937$). Late-season counts of pups were positively correlated with peak-season adult male counts at SMI ($r^2=0.914$) and at SNI ($r^2=0.805$).

DISCUSSION

The small amount of variability between replicate counts of pups, adult-females-plus-weaned-pups, and of males from 126 mm format vertical aerial photographs taken in 1988 and 1989 indicates that single counts are accurate indicators of their numbers. Dead pup counts are the least precise of the counts, most likely due to subjectivity of the reader. These dead pup counts are probably only of minimal value as indicators of pup mortality and are about 1/2 of the 2.5-3.1% pup mortality reported from field observations at these rookeries (Stewart 1989). Young pups that die within the breeding aggregations are very difficult to detect in the photographs because they may be obscured by adults, covered by sand, or because they have not begun to decompose and resemble live pups.

The estimated number of pups produced at SMI, SNI, and SRI (as determined by counts from aerial photographs) was greater than that reported in previous years by Stewart (1989). The rookery at SMI has expanded eastward along the southern coastline since the mid 1970's (cf. Stewart 1989). The numbers of pups born at Point Bennett has decreased while the numbers of pups born between Crook Point to Cardwell Point increased. The rate of increase was faster for this latter area than other parts of the island (Figure 5). An increase in the number of pups born at the western end of SRI, (the closest island to SMI) also took

place between 1985 (two pups born: Stewart and Yochem 1986) and 1991 (86 pups born). Overall, the population of northern elephant seals at SMI and SRI increased between 1985 and 1991, but the population at SNI has been stable since 1989.

Most major assessments of southern elephant seals (Mirounga leonina) use peak-season counts of adult females or adult-females-plus-weaned-pups at or near peak-season, to track changes in the population (McCann 1985, McCann and Rothery 1988, Pascal 1985, van Aarde 1980). Our peak-season counts of adult-females-plus-weaned-pups consistently exceeded the late season pup count by 3-9% (adding in dead pups to both does not change the percentages) and were positively correlated for each island, indicating that the count of adult-females-plus-weaned-pups would also be a good measure of pup production in the population if the late season pup count is not available. Factors which would tend to cause the difference between the two counts include unobserved pup mortality (after the first count), or females who have lost a pup or are not pregnant at the time of the peak-season count of adult females.

The limiting factor in conducting aerial photographic surveys is missed coverage. We believe that the portion of the northern shoreline of SMI that was not photographed in 1985 and 1986 did not significantly affect the total count because of low counts obtained for those areas in 1988 through 1991. In 1987,

because large areas of SMI were missed, estimates of total pups produced were not considered reliable. A few areas were also not photographed in 1988, but we also believe they represent very few seals and do not have a significant affect on the total count.

Northern elephant seals are ideally suited for high quality large format vertical aerial photographic studies because of their large size and sexual dimorphism, and because of their propensity to seek open sandy beaches to haul out on and breed. Vertical photographic censuses of elephant seals greatly reduce the amount of disturbance to the animals during the breeding season compared to censuses conducted on the ground. Large-format photographs makes it easier to count large aggregations of seals than photographs taken with medium (70 mm) or small format (35 mm) cameras. Another advantage is that large and remote colonies can be counted easily and accurately.

The photographs, by recording an event in the breeding season, can be used for other purposes. By determining scale in the photographs (easily done by measuring large logs, or distances between logs and rocks, or by placing photographic markers at known distances apart prior to the flight), it is possible to determine lengths of individuals and the surface area to calculate density of seals and habitat use. Photographs can also be used for behavioral studies, such as harem structure and nearest neighbor analysis. These photographs, unlike notes kept

in a record book, can always be re-examined in the future to answer new questions about northern elephant seals.

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LITERATURE CITED

Antonelis, G. A., S. Leatherwood, and D. K. Odell.

1981. Population growth and censuses of the northern elephant seal, Mirounga angustirostris, on the California Channel Islands, 1958-1978. U.S. Fishery Bulletin 79:562-567.

Bartholomew, G. A. and R. A. Boolootian.

1960. Numbers and population structure of the pinnipeds on the California Channel Islands. J. Mamm. 41:366-375.

Boveng, P., D. P. DeMaster, and B. S. Stewart.

1988. Dynamic response analysis. III. A consistency filter and application to four northern elephant seal colonies. Marine Mammal Science 4:210-222.

Braham, H. W.

1974. The California sea lion on islands off the coast of San Luis Obispo County, California. Calif. Fish and Game 60:79-83.

Carlisle, J. G. and J. A. Aplin.

1966. Sea lion census for 1965 including counts of other California pinnipeds. Calif. Fish and Game 52:119-120.

Cooper, C. F. and B. S. Stewart.

1983. Demography of northern elephant seals, 1911-1982. Science 219:969-971.

Gerrodette, T.

1988. Dynamic response analysis. II. Evaluation of dynamic response analysis in a simulated no-harvest case. Marine Mammal Science 4:196-209.

Goodman, D.

1988. Dynamic response analysis. I. Qualitative estimation of stock status relative to maximum net productivity level from observed dynamics. Marine Mammal Science 4:183-195.

Hanan, D. A., J. Scholl, M. Herder, and K. Waldron

1985. Harbor seal, Phoca vitulina richardsi, censuses in California, April and June 1983. In: D. A. Hanan. California Department of Fish and Game, coastal marine mammal study, annual report for the period July 1, 1982-June 30, 1983. Southwest Fisheries Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, Calif. Admin. Rept. LJ-85-10C.

Hanan, D. A., J. Scholl, and S. Diamond

1986a. Harbor seal, Phoca vitulina richardsi, census in California, June 25-30, 1984. In: D. A. Hanan. California Department of Fish and Game, coastal marine mammal study, annual report for the period July 1, 1983-June 30, 1984. Southwest Fisheries Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, Calif. Admin. Rept. LJ-86-16C.

Hanan, D. A., J. Scholl, and S. Diamond

1986b. Harbor seal, Phoca vitulina richardsi, census in California, May 28-31 June 25-30, 1985. In: D. A. Hanan. California Department of Fish and Game, coastal marine mammal study, annual report for the period July 1, 1984-June 30, 1985. Southwest Fisheries Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, Calif. Admin. Rept. LJ-86-25C.

Hiby, A. R., D. Thompson and A. J. Ward

1988. Census of grey seals by aerial photography. Photogrammetric Record 127:589-594.

Lavigne, D. M.

1976. Counting harp seals with ultraviolet photography. Polar Rec. 18:269-277.

Lavigne, D. M., S. Innes, K. Kalpakis, and K. Ronald

1975. An aerial census of Western Atlantic harp seals (Pagophilus groenlandicus) using ultraviolet photography. FAO Scientific Consultation on Marine Mammals, Bergen, Norway, 31 August-9 September 1976, ACMRR/MM/SC/33. 9pp.

Lavigne, D. M., S. Innes and W. Barchard

1980. The 1977 census on Western Atlantic harp seals, Pagophilus groenlandicus. ICNAF Selected Papers Number 6:55-70.

Mate, B. R.

1977. Aerial censusing of pinnipeds in the Eastern Pacific for assessment of population numbers, migratory distributions, rookery stability, breeding effort, and recruitment. Final Rep. U.S. Mar. Mamm. Comm. MM5AC001.

McCann, T. S.

1985. Size, status, and demography of southern elephant seal, (Mirounga leonina) populations. In J. K. Ling and M. M. Bryden (editors), Studies of sea mammals in south latitudes, p. 1-17. South Australian Museum.

McCann, T. S. and P. Rothery.

1988. Population size and status of the southern elephant seal (Mirounga leonina) at South Georgia, 1951-1985. Polar Biology 8:305-309.

Odell, D. K.

1971. Censuses of pinnipeds breeding on the California Channel Islands. J. Mamm. 52:187-190.

Pascal, M.

1985. Numerical changes in the population of elephant seals (Mirounga leonina L) in the Kerguelen Archipelago during the past 30 years. In J. R. Beddington, R. J. Beverton, and D. M. Lavigne (editors), Marine Mammals and Fisheries, p. 170-186. George Allen & Unwin, London.

Ripley, Wm. E., Cox, K. W. and J. L. Baxter.

1962. California sea lion census for 1958, 1960, and 1961. Calif. Fish and Game 48:228-231.

Stewart, B. S. and P. K. Yochem.

1984. Seasonal abundance of pinnipeds at San Nicolas Island, California, 1980-1982. Bull. Southern California Acad. Sci. 83:121-132.

Stewart, B. S. and P. K. Yochem.

1986. Northern elephant seals breeding at Santa Rosa Island, California. J. Mammal. 67:402-403.

Stewart, B. S.

1989. The ecology and population biology of the northern elephant seal, Mirounga angustirostris Gill 1866, on the Southern California Channel Islands. Ph.D. Thesis, University of California, Los Angeles, 195 p.

Shaughnessy, P. D.

1987. Population size of the cape fur seal Arctocephalus pusillus. 1. From aerial photography. Investl. Rep. Sea Fish. Inst. S. Afr. 130:1-56.

Taylor, R. H.

1982. New Zealand fur seals at the Bounty Islands. New Zealand Journal of Marine and Freshwater Research, 16:1-9.

van Aarde, R. J.

1980. Fluctuations in the population of southern elephant seals (Mirounga leonina) at Kerguelen Island. S. Afr. J. Zool. 15:99-106.

Table 1. Dates northern elephant seals were photographed at San Miguel Island (SMI), San Nicolas Island (SNI), and Santa Rosa Island (SRI) and camera format (i.e. film size) used.

Year	Island	Peak season	Late season	Camera format
1985	SMI	January 31	February 22	228 mm
1986	SMI	February 1	February 21	228 mm
1987	SMI	February 1-2		126 mm
1988	SMI	February 1	February 15	126 mm
	SNI		February 15	126 mm
1989	SMI, SNI	January 28	February 16	126 mm
1990	SMI, SNI, SRI	February 3	February 19	126 mm
1991	SMI, SRI	February 1	February 18	126 mm
	SNI	February 2	February 18	126 mm

Table 2. Replicate counts of northern elephant seals counted from 126 mm format aerial color photographs taken at San Miguel Island, California in 1988 and 1989.

		Peak Season				Late Season	
		Pups		Adult ♀ +		Pups	
Year	Counter	Live	Dead	Weaned pups	Adult ♂	Live	Dead
1988	1	10,146	168	12,022	1,705	10,901	182
	1	10,207	180	11,970	1,731	10,851	129
	2	10,053	118	12,044	1,684	10,595	161
1989	1	10,114	147	11,803	1,663	11,117	175
	1	10,183	129	11,863	1,740	11,266	145
	2	10,048	186	11,698	1,719	11,237	171
	3	10,217	181	11,878	1,748	11,142	156

Table 3. Coefficients of variation for replicate counts of northern elephant seals from 126 mm format aerial color photographs taken at San Miguel Island, California in 1988 and 1989.

	Peak Season				Late Season	
	Pups		Adult ♀ +		Pups	
Year	Live	Dead	Weaned pups	Adult ♂	Live	Dead
1988	0.0077	0.2117	0.0032	0.0138	0.0152	0.0880
1989	0.0074	0.1702	0.0069	0.0223	0.0065	0.0856

Table 4. Northern elephant seals counted from 228 mm format (1985 and 1986) and 126 mm format (1987-1991) aerial color photographs taken at San Miguel Island, California. Visual observer counts were made during photo flight for areas F, G, and portions of E in 1988 and 1989. Areas E, F, and G were not surveyed 1985 through 1987. No total is given for 1987 due to incomplete photo coverage. No photographic survey was conducted during late season in 1987 (blank area).

		Peak Season				Late Season	
		Pups		Adult ♀ +		Pups	
Year	Area	Live	Dead	Weaned pups	Adult ♂	Live	Dead
1985	A	1,342	?[1]	1,451	191	1,409	?
	B	1,415	?	1,440	163	1,440	?
	C	1,210	?	1,316	82	1,240	?
	D	5,135	?	5,614	1,076	5,496	?
	Total	9,102	?	9,821	1,512	9,585	?
1986	A	1,778	?	1,893	232	1,774	?
	B	1,698	?	1,763	240	1,664	?
	C	1,113	?	1,164	116	1,153	?
	D	5,033	?	5,202	1,019	4,964	?
	Total	9,622	?	10,022	1,607	9,555	?
1987	A	IPC[2]	IPC	IPC	IPC		
	B	1,778	26	1,955	235		
	C	1,098	10	1,227	77		
	D	4,840	84	5,473	969		
1988	A	2,639	27	3,103	339	2,879	33
	B	1,565	22	1,851	195	1,794	26
	C	1,012	15	1,252	107	1,044	7
	D	4,852	104	5,731	1,057	5,110	116
	E	78	0	85	7	74	0
	F,G	0	0	0	0	0	0
	Total	10,146	168	12,022	1,705	10,901	182
1989	A	3,197	39	3,665	441	3,510	45
	B	1,714	30	1,968	245	1,821	24
	C	935	9	1,097	135	1,006	10
	D	4,163	67	4,945	825	4,653	96
	E	104	2	127	14	126	0
	F	0	0	0	1	0	0
	G	1	0	1	2	1	0
	Total	10,114	147	11,803	1,663	11,117	175

[1]? = Data not obtained from photographs
[2]IPC = Incomplete Photo Coverage

Table 4.

		Peak Season				Late Season	
		Pups		Adult ♀ +		Pups	
Year	Area	Live	Dead	Weaned pups	Adult ♂	Live	Dead
1990	A	4,390	49	4,707	574	4,399	58
	B	2,115	24	2,252	303	2,117	23
	C	1,069	8	1,165	104	1,100	11
	D	4,444	77	4,842	922	4,459	91
	E	164	0	177	53	162	0
	F	0	0	1	31	2	0
	G	3	0	3	3	2	0
	Total	12,185	158	13,147	1,990	12,241	183
1991	A	5028	58	5476	647	5099	65
	B	2387	29	2585	343	2379	25
	C	1090	14	1242	151	1104	9
	D	4206	79	4683	844	4273	63
	E	161	0	176	60	167	0
	F	2	0	2	13	2	0
	G	9	0	10	7	5	0
	Total	12,883	180	14,174	2,065	13,029	162

Table 5. Northern elephant seals counted from 126 mm format aerial color photographs taken at Santa Rosa Island, California. No photographic survey was conducted during peak season in 1990 (blank area).

	Peak Season				Late Season	
	Pups		Adult ♀ +		Pups	
Year	Live	Dead	Weaned pups	Adult ♂	Live	Dead
1990					23	0
1991	86	0	97	37	83	0

Table 6. Northern elephant seals counted from 126 mm format aerial color photographs taken over San Nicolas Island, California. Area D not surveyed during 1988 late-season and 1989 peak-season flights. No photographic survey was conducted during peak season in 1988 (blank area).

		Peak Season				Late Season	
		Pups		Adult ♀ +		Pups	
Year	Area	Live	Dead	Weaned pups	Adult ♂	Live	Dead
1988	A					689	8
	B					1,174	16
	C					1,257	10
	Total					3,120	34
1989	A	1,049	13	1,226	127	1,164	16
	B	1,426	12	1,657	196	1,633	17
	C	1,649	25	2,004	226	1,887	30
	D					4	0
	Total	4,124	50	4,887	549	4,688	63
1990	A	1,120	11	1,202	127	1,065	14
	B	1,377	21	1,464	152	1,419	16
	C	1,593	23	1,749	190	1,585	22
	D	2	0	2	6	1	0
	Total	4,092	55	4,417	475	4,070	52
1991	A	1,144	14	1,239	125	1,117	15
	B	1,565	16	1,681	172	1,636	11
	C	1,783	37	1,974	188	1,783	25
	D	11	0	11	17	11	0
	Total	4,503	67	4,905	502	4,547	51

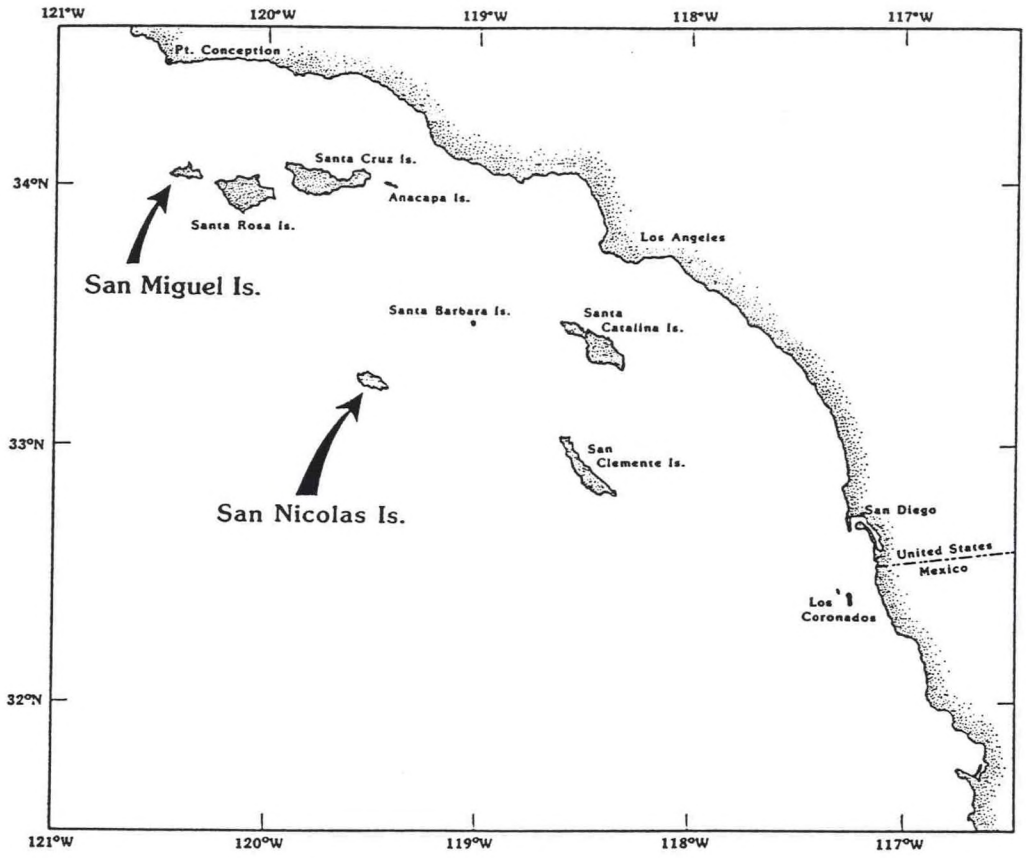

Figure 1. Map showing location of San Miguel Island and San Nicolas Island.

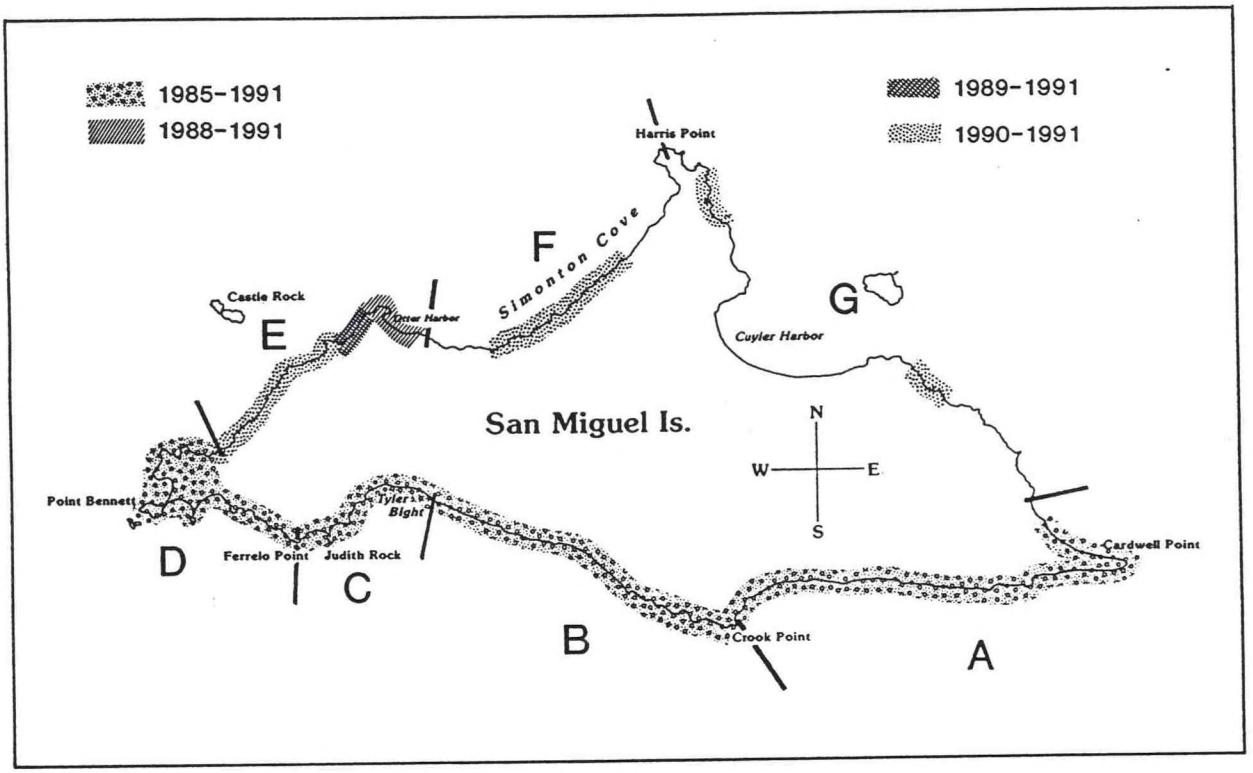

Figure 2. Map of San Miguel Island (SMI), California, showing shaded areas where northern elephant seals were photographed with 228 mm format (1985-86) and 126 mm format (1987-91) aerial color photographs and area codes used to document counts of northern elephant seals for specific areas of the island.

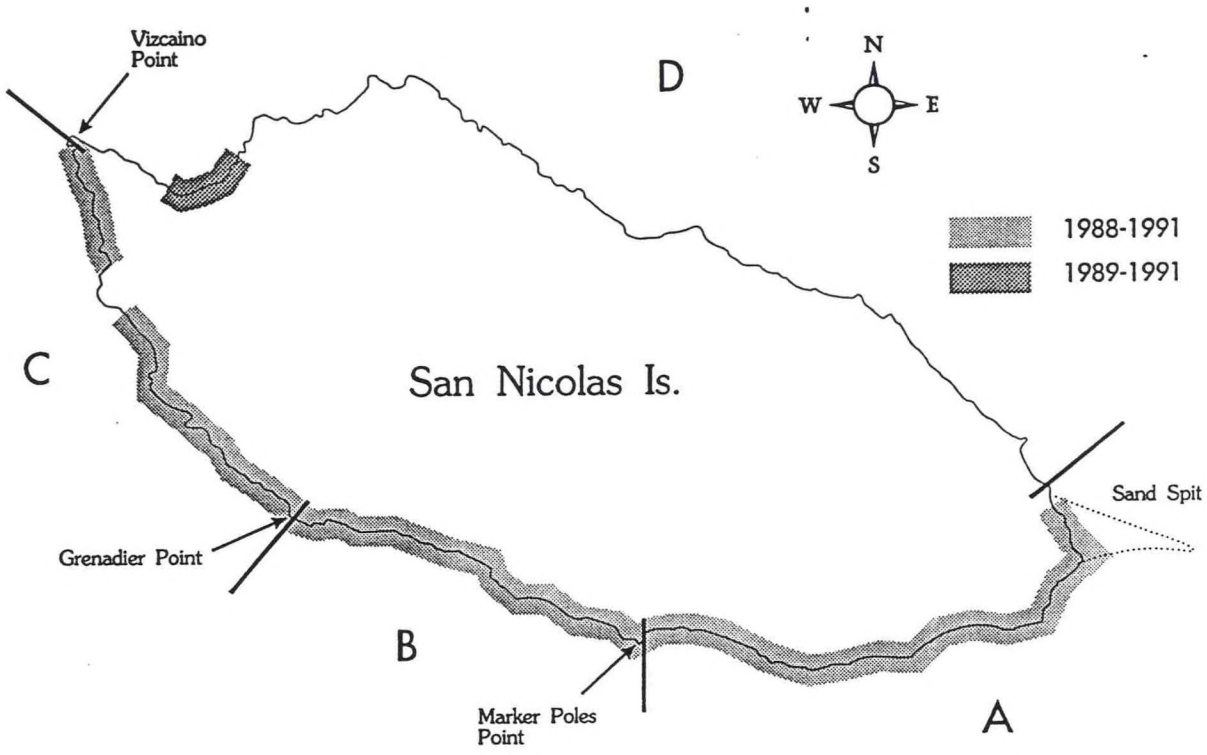

Figure 3. Map of San Nicolas Island (SNI), California, showing shaded areas where northern elephant seals were photographed with 126 mm format aerial color photographs and area codes used to document counts of northern elephant seals for specific areas of the island.

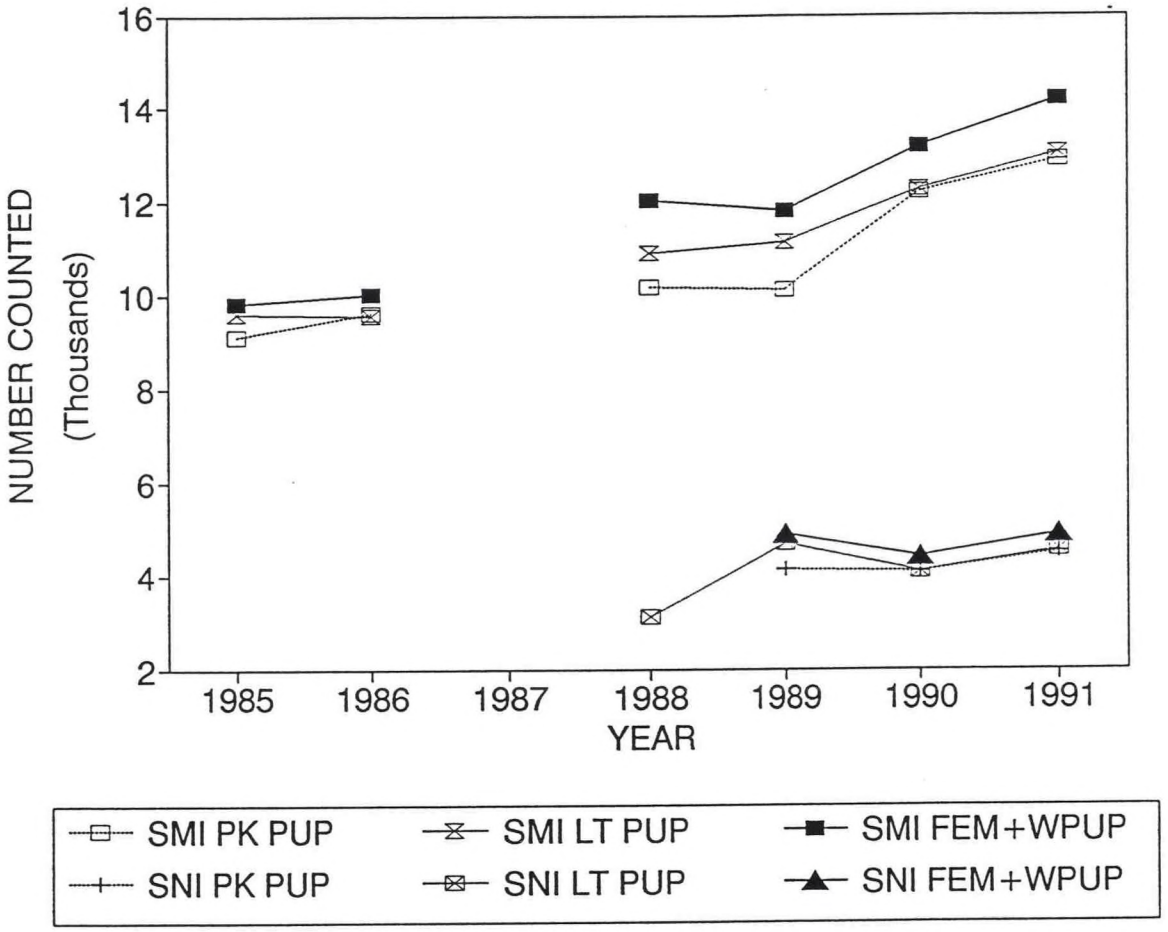

Figure 4. Comparison of northern elephant seal pup counts at peak breeding season (PK PUP) and late season (LT PUP) and the count of adult-females-plus-weaned-pups at peak season (FEM+WPUP) at San Miguel Island (SMI) and San Nicolas Island (SNI) for 1985, 1986, and 1988 through 1991.

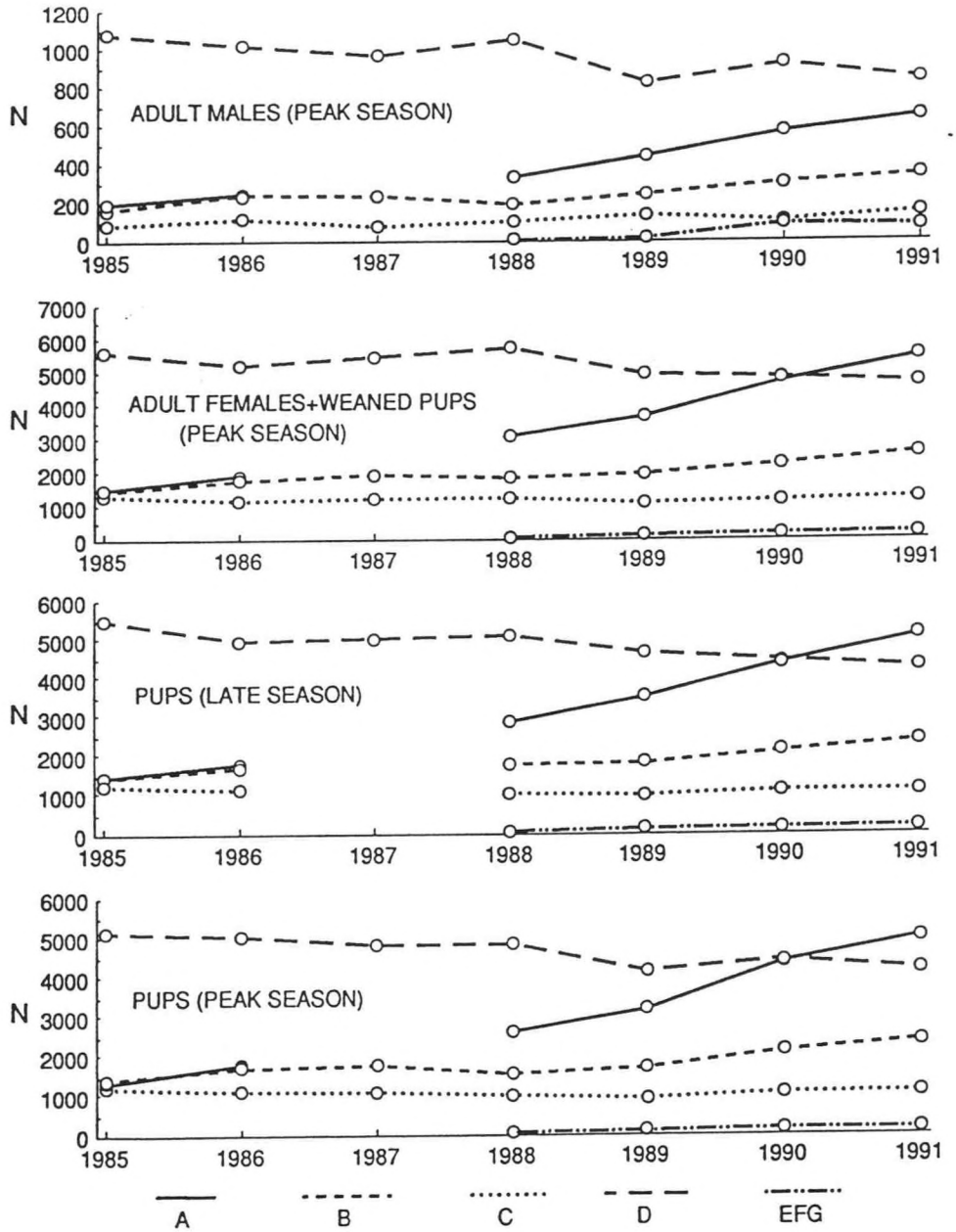

Figure 5. Northern elephant seal counts of adult males, adult-females-plus-weaned-pups, and pups during peak breeding season; and pups during late breeding season by area at San Miguel Island (SMI), California for 1985 through 1991. (Area A = Cardwell Pt. to Crook Pt.; Area B = Crook Pt. to Tyler Bight; Area C = Tyler Bight to Ferrelo Pt.; Area D = Ferrelo Pt. to Pt. Bennett; Area EFG = northern shore from Pt. Bennett to Cardwell Pt.)

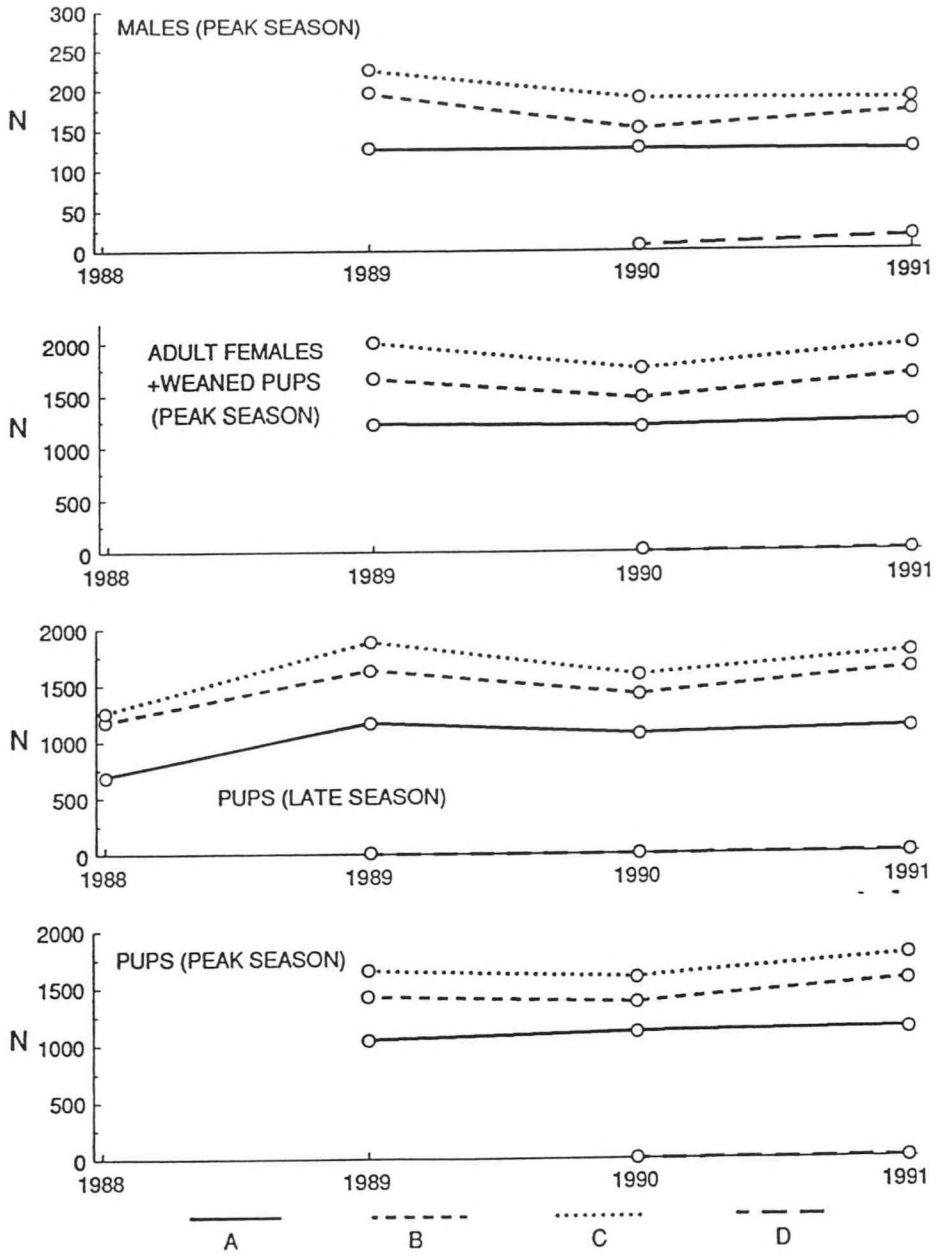

Figure 6. Northern elephant seal counts of adult males, adult-females-plus-weaned-pups, and pups during peak breeding season; and pups during late breeding season by area at San Nicolas Island (SNI), California for 1988 through 1991. (Area A = east end Sand Spit to Marker Poles Pt.; Area B = Marker Poles Pt. to Grenadier Pt.; Area C = Grenadier Pt. to Vizcaino Pt.; and Area D = northern shore from Vizcaino Pt. to east end Sand Spit)