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Fur Seal Investigations, 1993

by
Elizabeth H. Sinclair (editor)

U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

This report is a collection of papers that describe the 1993 research activities of the National Marine Mammal Laboratory on northern fur seals (Callorhinus ursinus).

Counts of adult male fur seals were conducted on the Pribilof Islands in the eastern Bering Sea in mid-July. A total of 18,251 adult male seals were counted, which is 5.25% less than the number counted in 1992, suggesting that the recently observed annual increase in male counts following the 1984 cessation of commercial harvesting of subadult males is subsiding.

Estimates of survival of the 1987 and 1988 cohorts of juvenile male northern fur seals tagged on St. Paul Island demonstrates the feasibility of obtaining estimates of male northern fur seal survival from tag returns. However, the level of precision in the estimates needs to be further refined.

An assessment of error in condition index measurements conducted on St. Paul Island in 1992 indicates that both length and weight are useful parameters in evaluating the condition of northern fur seal pups. The number of northern fur seal pups counted on San Miguel Island, California, conducted in late July (n = 2,045) was higher than in any year since the colony was discovered in 1968. However, mean pup weights were significantly lower than weights recorded in non-El Nino years.

A total population count was conducted on Bogoslof Island in the south central Bering Sea on 23 August. This was the first census since 1990 and the first since the northeast end of the island erupted in 1992. A total of 5,536 live fur seals were

counted, 890 of which were pups. Counts from 1992 and 1990 can not be directly compared since the 1990 census was conducted in July when aggression by territorial bulls makes it difficult to accurately count all areas (Baker and Kiyota 1992). The latest counts, however, appear to represent a near fourfold increase in population numbers since 1990.

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INTRODUCTION

by

Elizabeth H. Sinclair

The population status of northern fur seals (Callorhinus ursinus) on St. Paul Island has been monitored annually since 1911. Annual reports of research on the population status of northern fur seals on all U.S. breeding rookeries (including St. Paul Island) and throughout their pelagic North Pacific and Bering Sea range (Fig. 1) have been published since 1940, excluding a 3-year break during World War II. This series of publications, first produced by the Marine Mammal Biological Laboratory (later to become the National Marine Mammal Laboratory) represents one of the longest running documentations of life history patterns and dynamics of a wild animal population. From 1911 to 1984, northern fur seal research was carried out by Canada, Japan, the Soviet Union, and the United States under a convention for the conservation of North Pacific fur seals. Since 1984, studies have been conducted independently, but cooperatively by former member nations.

The breeding rookeries on St. Paul Island and St. George Island of the Pribilof Islands (Figs. 2 and 3) support the largest population (~ 800,000 animals) of northern fur seals in the world. Fur seals were commercially harvested on the Pribilof Islands by the Soviet Union from the late 1700s to 1867. Since then, the harvest has been under U.S. management. A moratorium on the commercial harvesting of fur seals was imposed on St. Paul

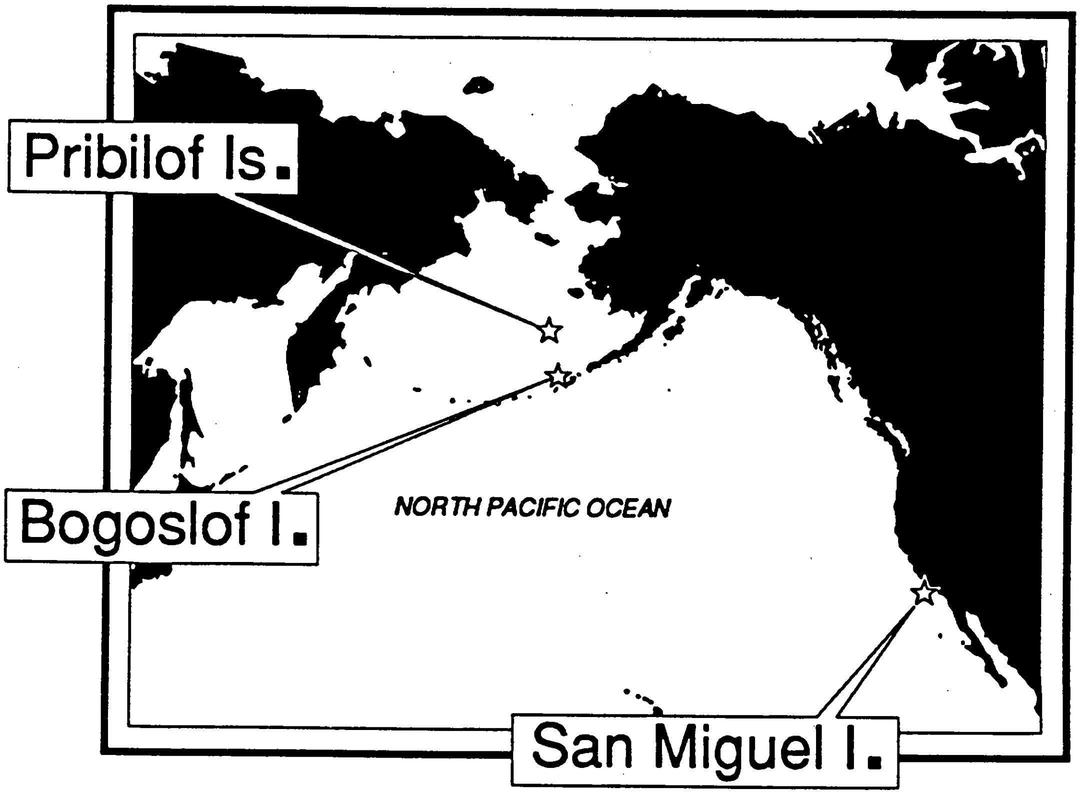

Figure 1.--Location of the four northern fur seal breeding rookeries within U.S. waters.

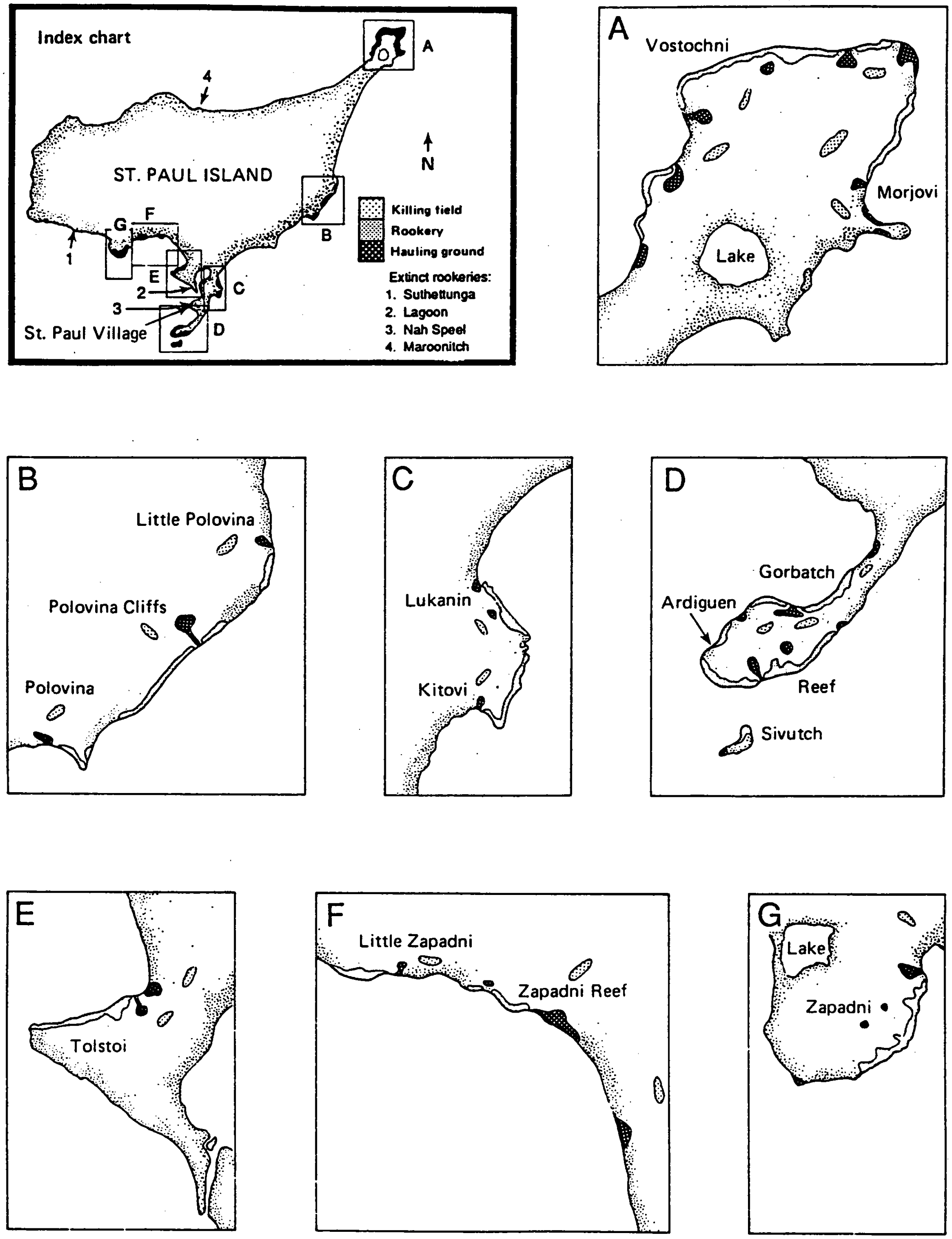

Figure 2.--Location of northern fur seal rookeries (present and extinct), hauling grounds, and harvesting areas, St. Paul Island, Alaska.

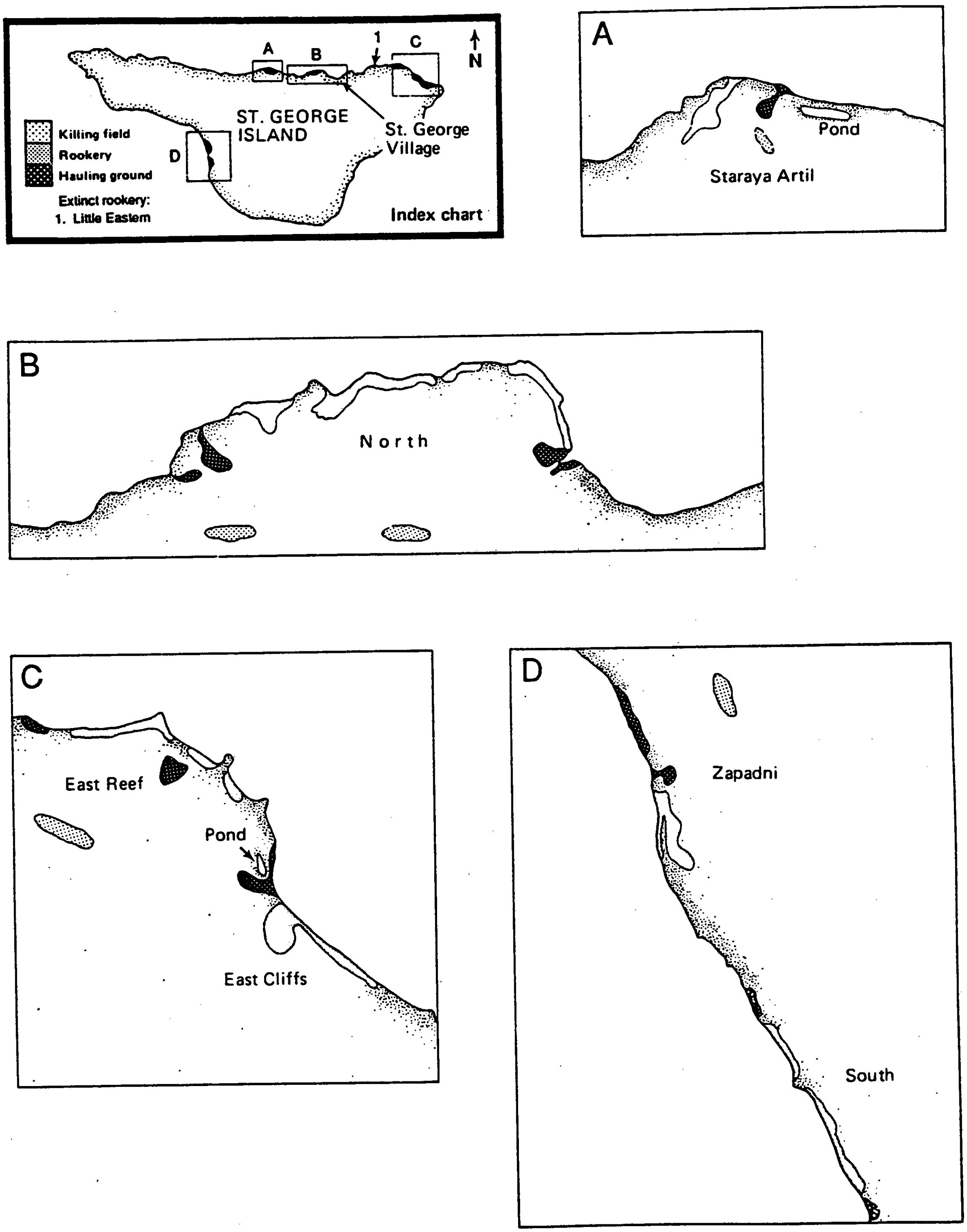

Figure 3.--Location of northern fur seal rookeries (present and extinct), hauling grounds, and harvesting areas, St. George Island, Alaska.

Island in 1984 and on St. George Island in 1973 because of the depressed population on the islands. Juvenile male fur seals, primarily 2- and 3-year-olds, are currently harvested only for subsistence purposes. There is no harvest of fur seals on Bogoslof Island, Alaska (total population size ~ 5,500 animals) or on San Miguel Island, California (breeding population size ~4,000 animals) (Figs. 4 and 5). However, juvenile males occasionally haul out on rookeries other than those on their natal island, and may be subject to subsistence harvest mortality.

Russian names given to some of the rookeries on the Pribilof Islands are translated in Table 1. Terms specific to fur seal research are defined in Appendix A. The remaining appendices contain tabulations of adult male northern fur seals on the Pribilof Islands (Appendix B), a model for estimating survival rates of male northern fur seals (Appendix C), tabulations of debris removal from entangled seals on the Pribilof Islands (Appendix D), and tabular data of pup tag records and condition measures of northern fur seals on San Miguel Island (Appendix E). Appendix F lists scientific staff involved in fur seal field research in 1993.

Research on northern fur seals in 1993 was conducted under Marine Mammal Permit number 837.

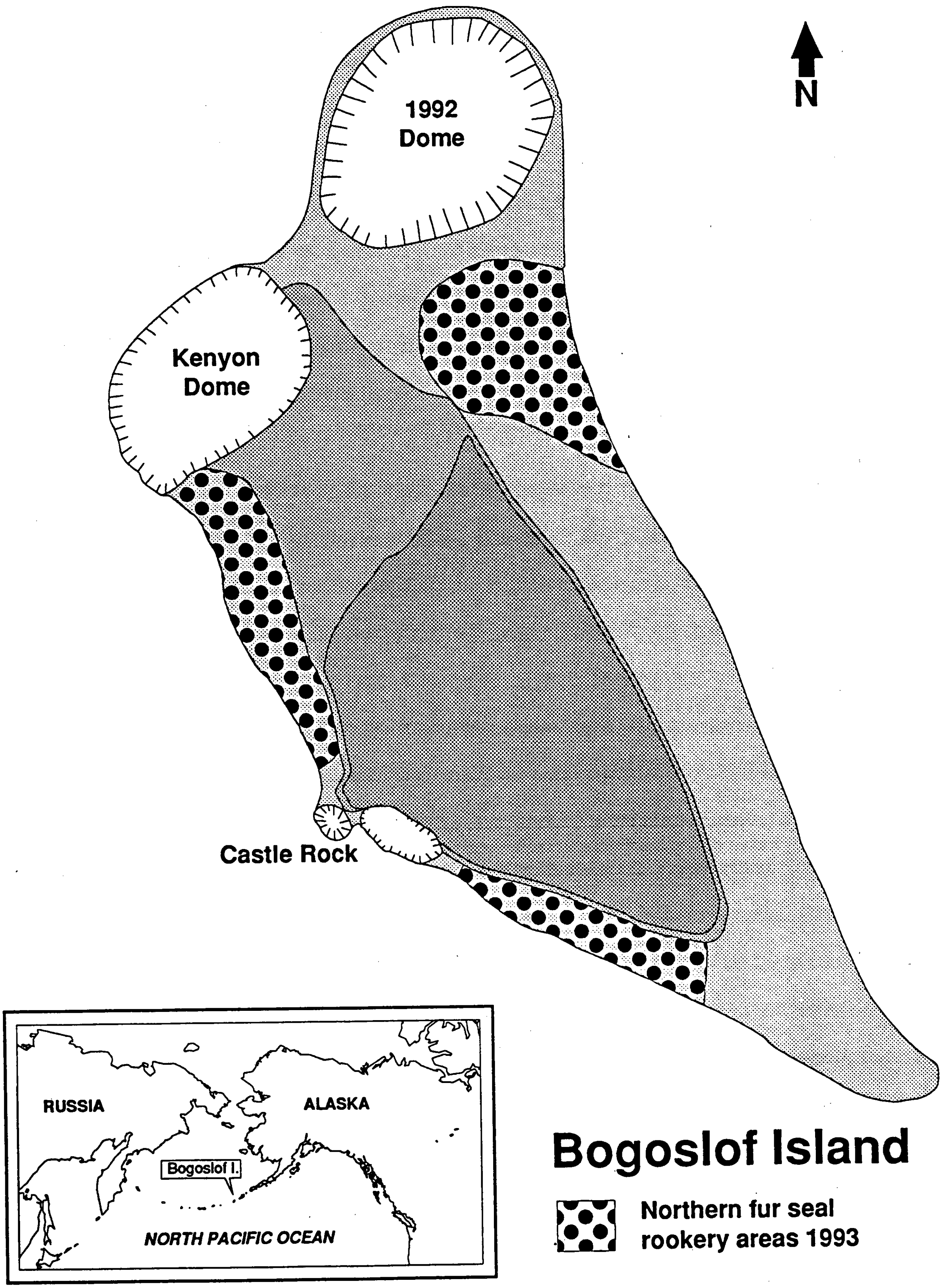

Figure 4. Fur seal rookeries on Bogoslof Island, Alaska, 1993. The 1993 census on Bogoslof was the first since the northeast end of the island erupted in volcanic activity in 1992 (Figure and description by Ream and Towell, Chapter 5, this volume).

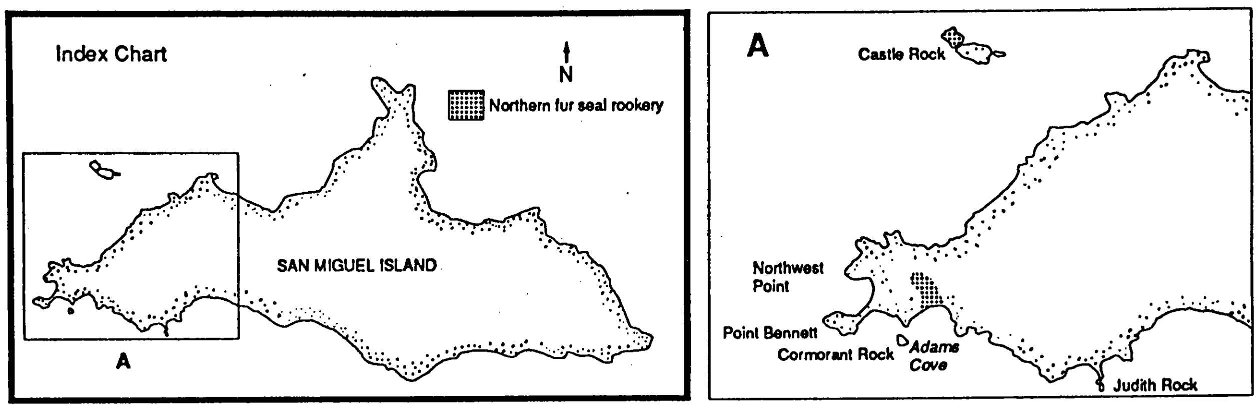

Figure 5.--Location of northern fur seal breeding colonies, San Miguel Island, California.

Table 1.--English translations of Russian names for Pribilof rookeries and hauling grounds.

Island and Russian name	English translation	Comments and derivation of name
St. Paul Island		
Vostochni	---	From "Novoctoshni" meaning "place of recent growth"; applied to Northeast Point, which was apparently at one time an island that has since been connected to St. Paul Island by drifting sand.
Morjovi	Walrus	Historically, walruses hauled out here in summer.
Polovina	Halfway	Halfway to Northeast Point from the village.
Kitovi	Of "kit"	When whaling fleets were active in the Bering Sea between 1849 and 1856, a large right whale killed by some ship's crew drifted ashore here.
Gorbatch	Humpback	Apparently refers to the "hump like" nature of the scoria slope above the rookery.
Tolstoi	Thick	In this case, thick headland on which the rookery is located.
Zapadni	West	Western part of the island.
Lukanin	---	Named after a Russian pioneer sailor who was said to have harvested over 5,000 sea otters from St. Paul Island in 1787.
Zoltoi (hauling ground)	Golden	Named to express the metallic shimmering of the sands.
St. George Island		
Staraya Artil	---	Old settlement or village. There was once a settlement or village adjacent to the rookery.
Sea Lion Rock		
Sivutch	Sea lion	These animals haul out but do not breed here.

POPULATION ASSESSMENT, PRIBILOF ISLANDS, ALASKA

by

Charles W. Fowler and Bruce W. Robson

In accordance with provisions originally established by the Interim Convention of Conservation of North Pacific Fur Seals, the National Marine Mammal Laboratory (NMML) monitors the population status of northern fur seals on the Pribilof Islands (St. Paul and St. George Islands). This species is now listed as depleted under terms of the Marine Mammal Protection Act, and any changes in population status are of significance to its management. Data on the number of adult males present on the islands and the number of seals taken in the subsistence harvest on both St. Paul and St. George Islands are collected annually. The number and sex composition of pups born on St. Paul and St. George Islands, and the number of dead animals of all ages and sexes are determined during even-numbered years.

METHODS

National Marine Fisheries Service personnel monitor the subsistence harvest of juvenile male northern fur seals. A crew is present throughout each harvest operation. A tally of the number of seals killed is recorded and maintained as part of a permanent record.

Counts of adult males are obtained each year according to methods established early in the 1900s as documented in Antonelis (1992). Counts are usually initiated about the 9th of July and conducted by a field crew that visits each rookery area on each island. At each rookery or hauling ground, counts are conducted from vantage points (natural or constructed tripods or catwalks).

Hauling grounds are also visited to count adult males without territories. Counts are divided into three categories: Adult males with territories containing females (Class 3), those occupying territories without females, and those without territories (see glossary in Appendix A). The last two categories are combined and reported as idle males.

Population Parameters

Seals Harvested

In 1993, 26 subsistence harvests of northern fur seals were conducted on St. Paul Island between 30 June and 6 August. Fourteen harvests were conducted on St. George Island between 1 July and 7 August. A total of 1,518 and 319 seals were killed on St. Paul Island and St. George Island, respectively (Table 2). All were juvenile male seals.

Living Adult Male Seals Counted

A total of 6,405 harem (see Appendix A for definition) and 9,301 idle adult male seals (bulls) were counted on St. Paul Island from 11 to 18 July (Appendix Table B-1). On St. George Island, 1,123 harem and 1,422 idle bulls were counted from 8 to 12 July (Appendix Table B-1). The number of adult males are indicated by class and rookery-hauling ground complex on St. Paul Island in Appendix Table B-2. The total number of adult bulls

Table 2.--Date, location, and number of juvenile male northern fur seals killed in subsistence harvest drives on St. Paul and St. George Islands, Alaska, in 1993.

Date	Rookery	Number killed
	St. Paul Island	
June 30	Reef	53
July 5	Kitovi	40
July 6	Zapadni	27
July 7	Polovina	48
July 8	Reef	34
July 9	Zapadni Reef	33
July 13	Zapadni	80
July 14	Polovina	45
July 15	Lukanin	33
July 16	Reef	43
July 20	Polovina	36
July 21	Zapadni Reef	56
July 22	Kitovi	50
July 23	Reef	51
July 24	Zapadni	68
July 26	Polovina	64
July 27	Zapadni Reef	41
July 28	Lukanin	60
July 29	North East Point	57
July 30	Zapadni	55
July 31	Reef	106
August 2	Polovina	70
August 3	Zapadni Reef	62
August 4	Lukanin	68
August 5	Zapadni	94
August 6	Reef	144
	Island total	1,518
	St. George Island	
July 1	North	18
July 6	Zapadni	36
July 8	North	17
July 10	Zapadni	20
July 13	Zapadni	11
July 15	North	17
July 17	Zapadni	28
July 20	Zapadni	29
July 24	Zapadni	13
July 27	Zapadni	19
July 29	North	35
July 31	Zapadni	32
August 3	North	23
August 7	Zapadni	21
	Island total	319

counted by rookery section are given in Appendix Table B-3.

The effects of the cessation of commercial harvesting of subadult male fur seals on St. Paul Island in 1984 appear to be subsiding. The increases in the counts of adult males of past years are not apparent for 1993. Although harem male counts continued to increase, idle male counts declined. The total (both harem and idle male counts) for both islands in 1993 was 1,011 (5.25%) less than in 1992. Harem counts on both islands were higher in 1993 than in 1992. The numbers of idle males counted on both islands declined with respect to 1992.

The increase in counts of harem males is a result of continued increase in the recruitment of seals of breeding age following the termination of the commercial harvest. The drop in numbers of idle males may signal the end of such increases in the next few years as the population reaches more of a balance in the age structure of males. This will happen when all of the cohorts of adult males are unharvested. Assuming that most breeding males are 8-13 years of age, the main effects of the terminated harvest are likely to have been experienced by 1996. Increases in harem males on St. George Island in recent years may be the result of seals recruited from the St. Paul Island population to breed on non-natal rookeries.

Estimates of Survival of the 1987 and 1988 Cohorts of Juvenile Male Northern Fur Seals Tagged on St. Paul Island, Alaska

by

Anne E. York

Reliable estimates of survival rates are crucial for understanding the dynamics of a population. The commercial harvest of sub-adult male northern fur seals provided an opportunity to determine the numbers of pups born and survival rates of juvenile male fur seals. In 1987, the National Marine Mammal Laboratory began a new tagging experiment designed to estimate the survival rates of juvenile males.

This was not the first tagging experiment of northern fur seals. Large numbers (up to 50,000 per year) of northern fur seals pups were tagged on the Pribilof Islands during 1947-68 (except in 1950). Tags were retrieved in the commercial harvest of sub-adult males; 1968 was the last year of large-scale tagging before 1987. Tagged sub-adult males were usually harvested like any other sub-adult male-- if they were judged to be within the length limits then in effect. The principal purposes of the earlier tagging study were to estimate the number of pups born, to determine intermixture rates among rookeries, and to estimate the survivorship of males from age 0-3 years.

Several attempts at estimating the survival rates of northern fur seals have been made in the past (Chapman 1964). The estimate of the number of pups born was obtained by tagging a known number of pups and retrieving tags in the commercial harvest. Estimates of survival were completely dependent on the quality of the estimate of numbers of pups born. By 1963, it was clear that the estimates of pup production based on tagging greatly overestimated the size of the population because of biased estimates of tag loss (Roppel et al. 1965, Chapman 1964), but by that time, the shearing-sampling method had been developed for directly estimating the numbers of pups born (Chapman and Johnson 1968). As a consequence of the overestimation of the numbers of pups born, the early estimates of survival to age 3 years based on tagging were negatively biased.

Lander (1975) developed a method of estimating the natural survival rate of juvenile male northern fur seals from birth to age 2 years using returns from the commercial harvest. Lander's basic assumption in deriving his survival estimates was that annual survival from ages 2-5 years was the same. Estimates of survival, based on Lander's method, provided a rough index of the relative survival of the various cohorts, and the resulting estimates have been useful for modeling the population dynamics of the St. Paul Island and Robben Island populations (e.g., York and Hartley 1981, Frisman et al. 1982, Trites 1984). Lander's method requires an estimate of the size of cohort at birth and numbers of fur seals harvested at ages 2-5 years. After 1984, there were no commercial harvests, so survival estimates are not available using that method for cohorts born after 1979 (those that would have had fur seals younger than 5 years after 1984).

When it was realized that survival estimates of juvenile male fur seals would not be available after the cessation of commercial harvesting (1984), fur seal scientists from the National Marine Mammal Laboratory decided to try to measure survival of young seals from resighting tagged animals in roundups that were intended to simulate the harvesting process without killing animals. Previous tagging experiments had suffered high tag loss rates (5% - 10% per year), and a new stainless steel rounded-post monel tag was designed (Antonelis 1992). The tagging experiment was designed to test the reliability of the new tag and to attempt to use the resighting information to estimate the rate of survival of juvenile male fur seals, and to compare the Lander and the capture/recapture methods of estimating survival.

METHODS

Experimental Design

Northern fur seal pups were marked on both foreflippers with modified (rounded-post) monel metal tags (Antonelis 1992) during August of 1987-90. In 1987 and 1988, both males and females were marked on all rookeries. During 1989 and 1990, only males were marked, except at two sites where future female reproductive studies were planned. Some of these seals, mostly males, were resighted at ages 2-5 years in roundups on the hauling grounds of St. Paul Island in July and early August of 1989-92 (Fowler et al. 1991; and Fowler et al. 1992). Roundups were not conducted after 1992 and therefore, data are not available after age 3 years for the 1989 cohort and 2 years for the 1990 cohort.

Sample sizes for the tagging experiment were determined using the equation in Appendix C, assuming the Jolly-Seber model with constant effort with the goal of achieving an estimated standard error of the estimate of survival from the time of tagging to age 2 years of less than 0.01 (York 1988). It was assumed that resighting rates would be similar to those reported by Gentry (1981) and survival rates similar to those reported by Lander (1979).

Parameter Estimation

The observations resulting from tagging and resighting fur seals are capture histories. Tagging took place shortly after birth and resighting occurred at ages 2, 3, 4, or 5 years. There are 16 possible capture histories corresponding to being seen or not seen at each age. Each fur seal in the experiment has its own capture history. These data can be modelled as a multinomial random variable in which the number of cells correspond to the numbers of observable capture histories (16 in this case), the observation is the number of fur seals with that capture history, and the expected values for each observation are functions of the numbers of fur seals tagged, the survival rates, capture probabilities, rates of tag loss, etc. Appendix C shows the calculations necessary to obtain the expected number of fur seals with a given capture history. For estimating parameters for the 1987 cohort, there are 16 observable capture histories, 8 for the 1988 cohort, 4 for the 1989 cohort, and 2 for the 1990 cohort. To maintain consistency, estimates in this report are derived only for the 1987 and 1988 cohorts using the recaptures at ages 2, 3, and 4 years, with 8 histories each. Parameter estimates were obtained using the methods of Burnham et al. (1987) using software documented in White (1992). This approach is very general and provides maximum likelihood estimates of probabilities for any multinomial model with specified constraints.

It is known that estimates of survival based on the Jolly-Seber model can be substantially biased when effort varies across years. We know that the arrival pattern of fur seals varies with age (Bigg 1990). Gentry (1981) shows the on-shore and at-sea patterns vary substantially among individuals, and both the timing and the intensity of sampling affect capture probability. Table 3 shows number of days of work and number of fur seals judged to be harvestable size rounded up each year. The number of days of effort in 1989 was substantially less than other years and the total number of fur seals rounded up were fewer in 1992 than either 1990 or 1991. To address this problem, the model in Appendix C was modified by including effort parameters which adjusted the probabilities of resighting a fur seal proportionally to days of effort for the particular year, relative to 1992 (Table 3).

Tag Loss

Maximum likelihood estimates of double tag loss were obtained using the method of Bishop et al. 1975 (Chapter 6).

Each cohort-age combination can be viewed as a multinomial random variable with 4 cells:

		Right tag present		
		Yes	No	Total
Left tag present	Yes	x_{11}	x_{12}	$x_{11}+x_{12}$
	No	x_{21}	x_{22}	
	Total	$x_{11}+x_{21}$		Total $=\hat{T}$

The fourth cell (both tags missing), x_{22}, is not observed. The maximum likelihood estimate of the number of fur seals with double tag loss is $x_{12}\ x_{21}/x_{11}$, and the estimates of the total number of fur seals, $\hat{T}$, is $(x_{11}+x_{12})\ (x_{21}+x_{11})/x_{11}$. The estimated variance of $\hat{T}$ is $(\hat{T}\ x_{12}\ x_{21}/x_{11})^2$; the variance of $\hat{x}_{22}$ can be estimated via the delta-method (recalling the assumption that (x_{11},x_{12},x_{21}) is a trinomial (T, p11, p12, p21) random variable. A bootstrap simulation (1,000 replicates) was also performed to verify the calculation of the variance from the maximum likelihood fit. Tests of hypotheses of equality of tag loss rates between right tag and left tag, between age groups, and cohorts were done using a general linear model (McCullagh and Nelder 1983) assuming that the tag loss on the right side was distributed as a binomial (n,p) random variable where n is the total observed number of tags lost, and p is the fraction of tags

Table 3.--Number of days of effort and numbers of fur seals of harvestable size rounded up on the haul outs of St. Paul, Alaska 1989-1992.

Year	Days of Effort	Number of fur seals	Days of effort relative to 1992	Total fur seals relative to 1990
1989	11	18,585	0.367	0.719
1990	28	25,829	0.933	1.000
1991	28	22,524	0.933	0.872
1992	30	17,630	1.000	0.683

lost from the right side. Models were fit using the statistical package Splus.

Survival rates

Estimates of survival and capture probabilities were obtained using the program SURVIVE (White 1992). SURVIVE is a very flexible program that provides maximum likelihood estimates of probabilities for any multinomial model with specified constraints; SURVIVE is not particularly user-friendly, and the expectations of each model of interest must be specified as code in Fortran. Parameter estimates of the models were adjusted for double tag loss by adjusting the numbers of releases of cohort c at age j by dividing the observed number by $1-t_{cj}$, where t_{cj} is the double tag loss rate for cohort c at age j. The variance of the survival estimates were adjusted using the delta method (Appendix C).

Models of Interest

The derivation of the model in Appendix C assumes constant annual survival during ages 2-4 years; these correspond to the assumptions of Lander (1979) and form the base model (H0) from which further constraints are made. Table 4 lists the simple hypotheses of interest relative to the equations in Appendix C. For cohort c, $\Phi(0,c)$ is the survival from the time of tagging to age 2, $\Phi(2,c)$, the survival from age 2 to 3, and $\Phi(3,c)$ the survival from age 3 to 4 for cohort c; $p(k,c)$ is the probability of recapture of a fur seal of age k from the cohort i (k = 2, 3, or 4; c= 1987 or 1988). With respect to this notation, H0 corresponds to $\Phi(2,c) = \Phi(3,c)$ for c = 1987 and 1988. This

Table 4.--Definition of constraints of simple models for estimation of survival rates of juvenile male fur seals from tagging returns. See Appendix C for the development of formulae. Composite hypotheses can be tested hierarchically.

Model	Hypothesis	English Description
H0	$\Phi(3,87) = \Phi(4,87)$ and $\Phi(3,88) = \Phi(4,88)$	Survival ages 2-3 and 3-4 equal for each cohort
Models constraining survival parameters within age across cohorts		
HΦ0	$\Phi(0,87) = \Phi(0,88)$	Survival 0-2 same across cohorts
HΦ2	$\Phi(2,87) = \Phi(2,88)$	Survival 2-3 same across cohorts
HΦ3	$\Phi(3,87) = \Phi(3,88)$	Survival 3-4 same across cohorts
Models constraining survival parameters within cohort (c = 1987 or 1988)		
HΦ02c	$\Phi(0,c) = \Phi(2c)$	Survival age 0-2 and 2-3 same
Models constraining capture probabilities within age across cohorts		
Hp2	$p(2,87) = p(2,88)$	Capture probabilities age 2 equal
Hp3	$p(3,87) = p(3,88)$	Capture probabilities age 3 equal
Hp4	$p(4,87) = p(4,88)$	Capture probabilities age 4 equal
Models constraining the capture probabilities within cohorts (c = 1987 or 1988)		
Hp34c	$p(3,c) = p(4,c)$	Capture probabilities age 3 and 4 equal
Hp23c	$p(2,c) = p(3,c)$	Capture probabilities age 2 and 3 equal
Hp24i	$p(2,c) = p(4,c)$	Capture probabilities age 2 and 4 equal

means that the survival from age 2 to age 3 and from age 3 to age 4 is the same for each cohort, but that the values are not necessarily the same for both cohorts. Additional hypotheses with corresponding constraints (Table 4) can be tested (e.g., is the probability of capture at age 3 the same for both cohorts, or is the survival from age 3 to age 4 the same for both cohorts), models fit with those constraints, and the suitability or lack thereof can be determined using a likelihood ratio test. Only simple hypotheses are listed in Table 4. Subsequent models were derived from a step-wise procedure, in which parameters were eliminated from H0 if the addition to the deviance of the model was not increased with probability 0.15. Often when models are selected in this manner, there are some models with very similar goodness of fit characteristics and one particular model is not an overwhelming choice. In this case, if the choice of choosing models boiled down to constraining survival or resighting probabilities, I constrained the resighting probabilities since the purpose of the tagging experiment was to estimate the survival rates.

Other factors that could affect survival

Mass was determined for 15.3% of tagged male fur seals in 1987 and 40.2% in 1988. Shearing and sampling were completed (1987 on all rookeries, and 1988 on four sample rookeries) before tagging operations to estimate the number of pups born. Both mass and shearing group (sheared or not sheared) were recorded during tagging operations. The interrelationships of mass, shearing status, year class, and the probability of appearing in the roundups were determined using a linear model with mass as the dependent variable modeled as a function of the other 3 variables.

RESULTS

Tag Loss

Estimates of the rate of double tag loss (Table 5A, Fig. 6A, 6B,6C) show that the tag loss rate was higher for the 1987 cohort and increases with age. The bootstrap simulations (Table 5B) give estimated variances of the rate of double tag loss similar to the maximum likelihood estimates.

A general linear model fit to the tag loss data (Table 6) showed that there was no significant difference between the rate of loss of the right tag and the left tag across age (P = 0.94) or cohort (P = 0.74). The residual deviance of this model was 0.58 with 3 df (P = 0.90), indicating there was no

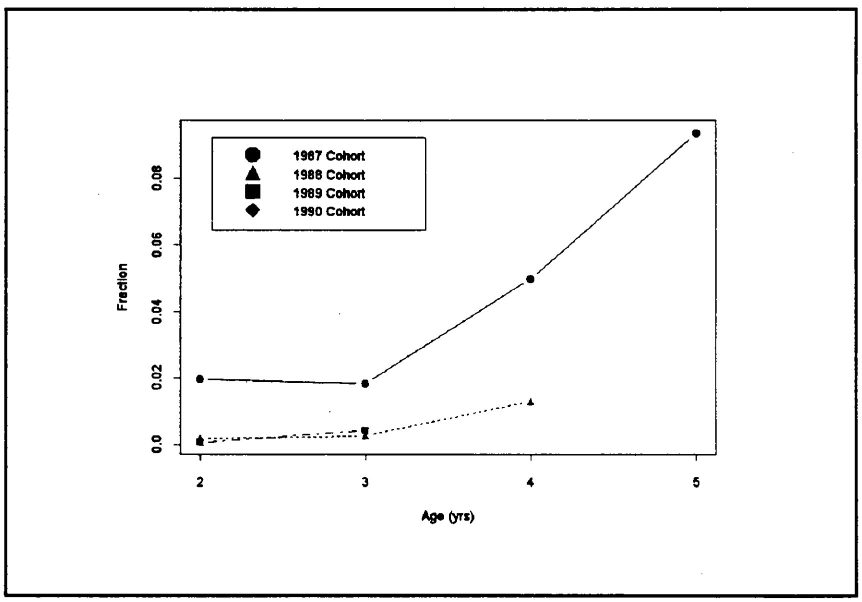

Figure 6. Estimated rate of double tag loss by age for male northern fur seals tagged at age 1 month on St. Paul Island, Alaska and resighted at ages 2-5 years during the summers of 1989-92.

Table 5A.--Numbers of fur seals in the roundups that appeared with both tags (x_{11}), only the right tag (x_{12}), and only the left tag (x_{21}); estimated number of fur seals with no tags, $\hat{x}_{22}$ estimated total number of tagged northern fur seals recaptured($\hat{N}$), with its standard error(SE $\hat{N}$), estimated fraction of double tag loss rate (Fraction) with its standard error (SE).

Cohort	Age	Both x_{11}	Right x_{12}	Left x_{22}	Total	$\hat{N}$	SE($\hat{N}$)	$\hat{x}_{22}$	Fraction	SE
1987	2	15	3	2	20	20.40	0.7376	0.40	0.0196	0.0307
	3	248	42	36	326	332.10	2.8573	6.10	0.0184	0.0074
	4	179	53	50	282	296.80	4.9546	14.80	0.0499	0.0126
	5	43	18	20	81	89.37	4.1714	8.37	0.0937	0.0308
1988	2	55	3	2	60	60.11	0.3453	0.11	0.0018	0.0055
	3	243	11	16	270	270.72	0.8983	0.72	0.0027	0.0031
	4	159	22	19	200	202.63	1.8304	2.63	0.0130	0.0079
1989	2	49	2	1	52	52.04	0.2082	0.04	0.0008	0.0039
	3	238	12	23	273	274.16	1.1558	1.16	0.0042	0.0039
1990	2	63	2	3	68	68.10	0.3208	0.10	0.0014	0.0045

Table 5B.--Bootstrap estimates of the rate of double tag loss (1,000 replicates). Mean, median, standard errors and bias-corrected confidence intervals (Efron and Tibshirani 1993).

Cohort	Age	Mean	Median	SE	95 % Confidence Interval	
1987	2	0.0208	0.0132	0.0229	0.0000	0.0833
	3	0.0184	0.0179	0.0042	0.0114	0.0276
	4	0.0394	0.0388	0.0141	0.0163	0.0669
	5	0.0953	0.0930	0.0302	0.0468	0.1619
1988	2	0.0019	0.0012	0.0019	0.0000	0.0065
	3	0.0027	0.0026	0.0011	0.0010	0.0051
	4	0.0129	0.0127	0.0041	0.0061	0.0220
1989	2	0.0008	0.0004	0.0011	0.0000	0.0037
	3	0.0043	0.0042	0.0016	0.0017	0.0080
1990	2	0.0014	0.0009	0.0015	0.0000	0.0060

Table 6A--Analysis of deviance table for the general linear model fitting loss of the right tag as a binomial(n,p) random variable, where n is the total number of fur seals that lost one tag and p is the fraction of those fur seals that lost the right tag. If there is no difference in the rate of right and left tag loss, p = 0.5.

Factor	Df	Deviance	P	Resid. Df	Resid Dev
Null	9	2.246098			
Age	3	0.418570	0.94	6	1.827528
Cohort	3	1.250834	0.74	3	0.576694

Table 6B.--Analysis of deviance table for the general linear model fitting loss of one tag on age and cohort. Loss of one tag is modelled as a binomial (n, p) random variable, where n is the total number of tagged fur seals recovered and p is the rate of tag loss (among recoveries). Categories of age are 2 and 3 combined, 4, and 5. Categories of cohort are 1987 and 1988, 1989, and 1990.

Factor	DF	Deviance	Resid Df	Resid. Dev
Null			9	126.2710
Age	2	74.92700	7	51.3440
Cohort>87	1	46.71167	6	4.6324
Age:Cohort>87	1	0.52087	5	4.1115

Table 6C.--Parameter estimates for model described in Table 7B. Parameter estimates are the logits of the rate of tag loss. The estimate for Ages 2 and 3 from the 1987 cohort is -1.1533, Age 4 1987 cohort is -1.1533 + .6007, etc.

	Value	SE	t
Intercept	-1.1533	0.1259	-9.161
Age 4	0.6007	0.1765	3.404
Age 5	1.0297	0.2558	4.026
Year>87	-1.0031	0.1753	-5.723
Age 4: Year>87	0.2005	0.2769	0.724

significant age-cohort interaction with respect to losing the right or left tag. The greatest discrepancy between right and left tag loss was for the 3 year old fur seals from the 1989 cohort (12 fur seals with the right tag and 23 with the left tag, $X^2 = 3.47$, 1 df, $P = 0.063$). A general linear model was fit with the response variable being the rate of loss of one tag. Tag loss rates were significantly higher for the 1987 cohort than the 1988-1990 cohorts ($P < 0.05$). Tag loss rates were not significantly different for age 2 and 3 ($P < 0.05$) for the 1987 cohort nor for the 1988-1990 cohorts. The rate of tag loss observed for 4-year-old fur seals from the 1988 cohort was higher than the combined rate for the 2-year-old fur seals from 1988-1990 and 3-year-old fur seals from 1988 and 1989 ($P<0.05$). The rate of loss for this group was not significantly different from the rate of loss for the 2- and 3-year-old fur seals from the 1987 cohort ($P < 0.05$) and was significantly lower than the rate of loss of 4-year-old fur seals from the 1987 cohort ($P < 0.05$).

Survival Rates

The raw data used to estimate survival rate are the capture histories in Table 7. Goodness of fit statistics for the various simple models described in Table 4 are in Table 8. Parameter estimates of the model under H0 appear in Table 9. The analyses of the simple hypotheses (Table 8) suggests that for any year the following hypotheses that can be rejected out of hand: a) survival from age 0 - 2 years equal to survival from 2 - 3 or 3 - 4 years ($\Phi_0 = \Phi_2$ or $\Phi_0 = \Phi_3$); b) probability of resighting at age 2 equal to probability or resighting at ages 3 or 4 ($p_2 = p_4$

Table 7.--Number of male northern fur seals tagged as pups on St. Paul Island in 1987 and 1988 and subsequently resighted on St. Paul Island, Alaska at ages 2-5 years (N) (0 indicates not resighted at the given age, 1 indicates resighted at the given age), number weighed at the time of tagging (Weighed), mean mass and standard error (SE) at the time of tagging.

2 year	3 year	4 year	5 year	N	Weighed	Mean mass	SE
				1987 Cohort			
0	0	0	0	3795	577	9.637	0.083
1	0	0	0	14	3	10.500	1.000
0	1	0	0	215	34	9.603	0.284
1	1	0	0	3	1	11.000	--
0	0	1	0	157	21	9.500	0.364
1	0	1	0	1	0	--	--
0	1	1	0	77	12	9.646	0.455
1	1	1	0	1	0	--	--
0	0	0	1	23	7	10.357	0.478
1	0	0	1	0	0	--	--
0	1	0	1	12	1	11.500	--
1	1	0	1	0	0	--	--
0	0	1	1	28	6	9.292	0.518
1	0	1	1	0	0	--	--
0	1	1	1	17	1	10.750	--
1	1	1	1	1	0	--	--
				1988 Cohort			
0	0	0	-	2619	1048	9.453	0.055
1	0	0	-	38	15	10.217	0.473
0	1	0	-	188	82	9.945	0.184
1	1	0	-	14	7	10.786	0.360
0	0	1	-	128	48	9.583	0.264
1	0	1	-	4	2	11.000	0.000
0	1	1	-	64	28	9.786	0.260
1	1	1	-	4	1	7.500	--

Table 8.--Results of fitting the simple models described in Table 6. Log-likelihood, degrees of freedom, Akaike information criterion (AIC), and X goodness of fit test of the given model (P_{X2}), decreased deviance (G^2)after fitting the given model under H0. P is the probability of a higher value of G^2 assuming it is distributed as X^2 with 1 df. Note that under H0, $\Phi_2 = \Phi_3$ so that $H\Phi_2$ and $H\Phi_3$ are the same. Models which fit the data better have larger log likelihoods, smaller AICs, smaller G^{2}, and higher value of P_{X^2} and P (HΦ0, HP3, and HP3488).

Model	Log Likelihood	df	AIC	P_{X^2}	G^2	P
H0	-33.82	2	87.65	0.15		
HΦ0	-33.87	3	85.74	0.27	0.1	0.756
HΦ23	-34.09	3	86.17	0.23	0.52	0.469
HΦ0287	-49.99	3	117.98	0	32.33	0
HΦ0288	-50.08	3	118.15	0	32.5	0
HP2	-34.78	3	87.56	0.13	1.92	0.167
HP3	-33.83	3	85.65	0.28	0.01	0.937
HP4	-34.43	3	86.85	0.17	1.21	0.272
HP3487	-35.05	3	88.10	0.1	2.45	0.118
HP3488	-33.83	3	85.66	0.28	0.01	0.911
HP2487	-87.85	3	193.69	0	108	0
HP2488	-82.65	3	183.29	0	97.65	0
HP2387	-98.57	3	215.14	0	129.5	0
HP2388	-122.81	3	263.62	0	178	0.000

Table 9.--Estimates of survival and capture probabilities for 1987 and 1988 cohorts of northern fur seals tagged on St. Paul Island, Ak. and recaptured at ages 2-4 years. Under H0, $\Phi_2(88) = \Phi_3(88)$ and $\Phi_2(87) = \Phi_3(87)$ (corresponds to the assumptions of Lander (1979)); H2 was derived from a step-wise procedure, in which parameters were eliminated from H0 if the addition to the deviance of the model was not increased with probability 0.15; under H2, p3(88)= p3(87), p3(88)= p4(88), and p2(88)= p2 (87).

Model: H2=H0 $Hp_3H_2Hp_{34}88Hp_2$					Model H0: $\Phi_2 88=\Phi_3 88$ and $\Phi_2 87 = \Phi_3 87$			
Parameter	Estimate	SE	Lower	Upper	Estimate	SE	Lower	Upper
$\Phi_0 88$ Survival 0-2 y	0.384	0.036	0.313	0.455	0.361	0.060	0.243	0.479
$\Phi_2 88$ Survival 2-3 y	0.689	0.046	0.598	0.779	0.729	0.136	0.462	0.996
$\Phi_3 88$ Survival 3-4 y	0.689	0.046	0.598	0.779	0.729	0.136	0.462	0.996
$p_2 88$ Capture Pr. 2 y	0.050	0.007	0.036	0.063	0.058	0.012	0.035	0.082
$p_3 88$ Capture Pr. 3 y	0.363	0.022	0.319	0.406	0.361	0.036	0.291	0.431
$p_4 88$ Capture Pr. 4 y	0.363	0.022	0.319	0.406	0.344	0.085	0.178	0.510
$\Phi_0 87$ Survival 0-2 y	0.326	0.026	0.275	0.377	0.405	0.138	0.135	0.675
$\Phi_2 87$ Survival 2-3 y	0.689	0.046	0.598	0.779	0.555	0.192	0.178	0.932
$\Phi_3 87$ Survival 3-4 y	0.689	0.046	0.598	0.779	0.555	0.192	0.178	0.932
$p_2 87$ Capture Pr. 2 y	0.050	0.007	0.036	0.063	0.031	0.013	0.006	0.056
$p_3 87$ Capture Pr. 3 y	0.363	0.022	0.319	0.406	0.364	0.029	0.307	0.422
$p_4 87$ Capture Pr. 4 y	0.474	0.052	0.373	0.575	0.588	0.217	0.162	1.013

or p_2 = p_3). On the other hand, several hypotheses cannot be rejected: a) Hp_3: p_3 88 = $p_3$87; b) Hp_4: p_4(88) = p_4(87). Constraints were made in a step-wise fashion, in order of their conditional likelihood given the previous model. The results of collapsing the model into a simpler and simpler model until no further simplification appeared reasonable (Table 9) resulted in a model (H2) with 6 degrees of freedom and included the hypotheses Hp_3, Hp_{34}(88), and Hp_2-- that is, probabilities of capture at age 3 and at age 2 are the same across cohorts, and the probability of capture at age 3 and 4 is the same for the 1988 cohort.

Under H0 (which is equivalent to the Lander assumptions), the survival from age 0-2 years was calculated to be 0.405 (SE = 0.138, CV = 34%) for the 1987 cohort and 0.361 (SE= 0.060, CV = 16.7%) for the 1988 cohort. The CVs decrease to 7.9% and 9.4% under H2. The CVs for the annual survival rate during the second and third year is 6.7% under H2 (the survival rate is common to both cohorts). Under H0, that survival rate is .729 (SE = 0.136, CV = 18.6%) and 0.555 (SE = .192, CV = 34.6%) for the 1988 and 1987 cohorts respectively. If we apply the Lander procedure to the tagging data, the survival estimate from birth to age 2 years is 0.246 for the 1987 cohort and 0.285 for the 1988 cohort, while the average annual survival during years 2-4 is 0.754 for the 1987 cohort and 0.769 for the 1988 cohort. The Lander procedure does not include any estimate of the variance of these estimates. The early survival rates based on the Lander method are within the 95% confidence intervals under H0, but not

H2. The estimates of survival during years 2 and 3 from the Lander procedure lie in the 95% confidence intervals under both H0 and H2.

Weight at the Time of Tagging and Shearing History

In an attempt to try to improve the survival rate estimates from the resighting of tags, weight and shearing-status at the time of tagging were considered as covariates (Table 10 A). There was evidence that there was probable interaction between returned status and shearing status (P = 0.066) and insufficient evidence to reject the 3-way interaction between year class, shearing status, and return status. A closer examination of the data reveals that no interaction between shearing and return status for the 1988 cohort (Table 10 B), but that the mean mass of sheared fur seals recaptured from the 1987 cohort was significantly less than the mean mass of non-sheared seals from the same cohort (Fig. 7, Table 10 C). Among the non-sheared animals (Table 10 D), there is statistical evidence that the animals that returned were heavier (P = .003) than those that did not return. The difference in mass (for the non-sheared fur seals) between year classes is significant at the 10% level (P = .092).

DISCUSSION

This report demonstrates that it is possible to obtain reasonable estimates of survival of male northern fur seals from tagging returns. The precision of the estimates is much less

Table 10.--Analysis of variance of weight at the time of tagging by year class, shearing and return status for the 1987 and 1988 cohorts of male northern fur seals tagged on St. Paul Island, Alaska, and captured at ages 2, 3, or 4 years.

A. All male fur seals, 1987 and 1988 cohorts.

Factor	DF	SS	MS	F	P
Year-class	1	7.312	7.312	2.213	0.137
Returned	1	22.167	22.167	6.710	0.010
Sheared	1	36.660	36.660	11.096	0.001
Year-class X Returned	1	7.375	7.375	2.232	0.135
Year-class X sheared	1	2.993	2.993	0.906	0.341
Returned X Sheared	1	11.163	11.163	3.379	0.066
Year-class X Returned X Sheared	1	7.499	7.499	2.270	0.132
Residuals	1886	6231.052	3.304		

B. Male fur seals 1988 cohort only

Factor	DF	SS	MS	F	P
Returned	1	28.239	28.239	9.210	0.002
Sheared	1	26.893	26.893	8.771	0.003
Returned X Sheared	1	0.245	0.245	0.080	0.777
Residuals	1227	3762.181	3.066		

C. Male fur seals 1987 cohort only

Factor	DF	SS	MS	F	P
Returned	1	0.358	0.358	0.095	0.757
Sheared	1	13.706	13.706	3.658	0.056
Returned X Sheared	1	18.417	18.417	4.916	0.027
Residuals	659	2468.870	3.746		

D. 1987 and 1988 cohorts non-sheared animals

Factor	DF	SS	MS	F	P
Year-class	1	9.393	9.393	2.841	0.092
Returned	1	30.111	30.111	9.107	0.003
Returned X Year-class	1	2.400	2.400	0.726	0.394
Residuals	1763	5829.203	3.306		

than was originally specified in the design of the experiment. The standard error was estimated at 3 to 6 times than originally proposed for the estimates of survival from birth to age 2 years. This was probably caused by an overly optimistic projection of the probable resighting rate. In the experimental design, those were based on harvest data (Lander 1979) and resighting rates by Gentry (1981) on St. George Island both of which averaged about 60% for 3 and 4 year old fur seals. The harvesting removed individuals and made the hauling grounds less crowded and perhaps attracted a larger fraction of individuals. In Gentry's study on St. George, each hauling ground was visited daily (Gentry 1981) and fur seals were resighted through spotting scopes and binoculars and were not physically recaptured. Some or all of these factors probably contributed to the low recapture rate and the lack of precision in the estimates.

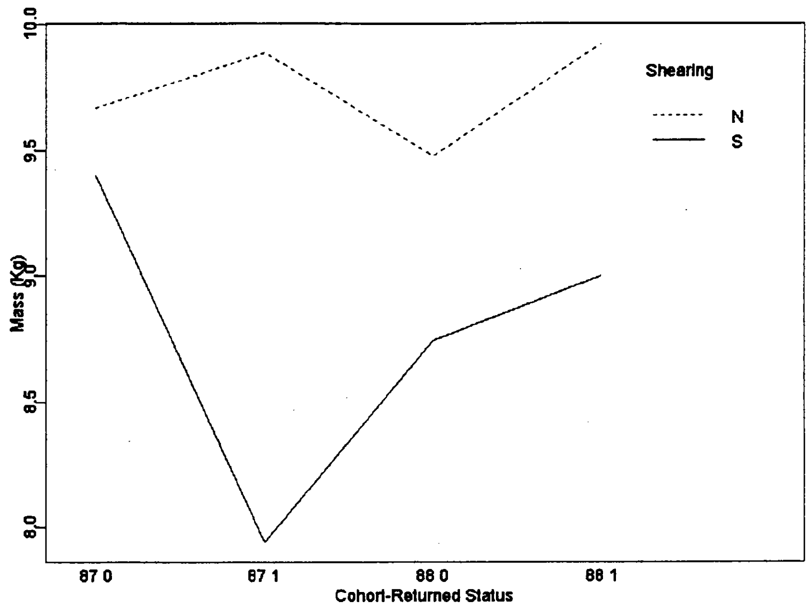

Figure 7. Mean mass (Kg) of male northern fur seals tagged in 1987 and 1988. S= Sheared, N= non-sheared. 0=not returned, 1 = returned.

The estimates of survival from 0 to age 2 years are much higher than the estimates derived from the Lander procedure of the same data. Lander's estimate of survival to age 2 is roughly 0.1 - 0.15 plus the fraction of fur seals harvested; thus, the lower resighting rate than harvest rate will cause these two estimates to be very different. Of the 7,379 males tagged in 1987 and 1988, only 988 (13.3%) had been resighted by age 4.

At present, it is not possible to adjust survival estimates using mass at the time of tagging, but improvements are continuously being made to the software so this may be possible soon.

ASSESSMENT OF MEASUREMENT ERROR IN WEIGHTS AND LENGTHS OF NORTHERN FUR SEAL PUPS IN 1992

by

Bruce W. Robson, George A. Antonelis, and Jeffrey L. Laake

Condition indices which utilize relationships between weight and length have been described for several species of pinnipeds and provide a means of assessing the health of a particular cohort (Boyd 1984, Boyd and McCann 1989, Doidge and Croxall 1989, Castellini 1990, Trites and Bigg 1992). Historically, only weight information has been collected from northern fur seal pups on the Pribilof Islands and larger pups have been shown to have higher post-weaning survival chances (Baker and Fowler 1992). On the Commander Islands, both weight and length have been used to assess growth and to derive a condition index for northern fur seal pups (Boltnev 1991). The reliability of these evaluations depends upon the collection of accurate measurements.

The purpose of this paper is to compare the magnitude of measurement error associated with length and weight data used to assess condition of northern fur seal pups on the Pribilof Islands. Repeated measurements were collected to examine the variation within measurements due to measurement error relative to the natural variation among individuals. The difference in measurement error between weight and length measurements was also compared.

METHODS

From 25 to 28 August 1992, length and weight information was collected from fur seal pups at four rookeries on St. Paul Island (Tolstoi, Reef, Vostochni, and Polovina Cliffs). Groups of approximately 50-100 pups were held using portable barricades or natural barriers at several locations on the rookery (Antonelis 1992). Isolated groups were chosen to ensure that all targeted pups were captured for sampling and to prevent escape by more mobile pups. The sex, length, and weight of each pup was determined. Standard length from the tip of the nose to the tip of the tail was measured to the nearest centimeter. One person held the pup so that the nose touched the end of the Acme Accu-Stretch measuring board while another person gently pulled on the rear-flippers and determined the length when the pup momentarily relaxed. Pups were weighed to the nearest .25 kg in a modified plastic bucket suspended from a hand-held spring scale (Antonelis 1992). Pups were marked on the foreflipper with a yellow livestock crayon to avoid unintentional repeat measurement.

For this study, a subsample of pups from each group was selected for repeat measurements. After being measured for the first time and released, individual pups were periodically chosen by the data recorder and sent through the measuring process a second time. Members of the crew collecting measurements were unaware which pups would be selected for a second set of measurements.

Data were analyzed using a random effects ANOVA as described in Bailey and Byrnes (1990) to evaluate the variability of repeated measurements on a given individual relative to the variation among individuals. The variance of length and weight measurements were partitioned into among-individual and within-individual components for analysis. Each type of measurement was then analyzed with respect to percent measurement error (%ME) which represented the percentage of total variance associated with measurement.

To evaluate possible sample session bias, we tested for significant differences in weight and length measurements (measurement 1 - measurement 2) using a paired t-test. A relationship between pup size (mean weight and length) and the absolute value of measurement difference was considered important if the Spearman rank correlation (r_s) was significantly different from zero (Snedecor and Cochran 1967). We also tested for significant correlation (r) in length and weight measurement differences (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

Two sets of measurements were collected on a subsample of 67 pups. The pups ranged in length from 63.0 to 86.5 cm (x = 78.48 cm, SD = 4.47)and in weight from 6.25 to 13.75 kg (x = 9.65 kg, SD = 1.78). The calculations and results for these data are summarized in Table 11.

The average difference between first and second measurements of weight did not differ significantly from zero (P = 0.82)

Table 11.--Results of calculations describing within (w) and among (a) seal variance associated with measurement error, percent measurement error (%ME) and coefficient of variation (cv) for length and weight of pups (N = 67) on St. Paul Island, Alaska, 1992.

	Within (w)				Among (a)		
	Average[1] (N = 67)	Standard deviation (w)[2]	%ME[3]	%CV[4]	Standard deviation (a)[5]	100-%ME[6]	%CV[7]
Length	78.48	0.906	3.95	1.15	4.467	96.05	5.69
Weight	9.65	0.188	1.11	1.95	1.779	98.89	18.44

1 Average of all measurements designated $\bar{L}$ for length and $\bar{W}$ for weight.

2 σ_W = the standard deviation within seal associated with measured error.

3 %ME = % of total variance for measurement = 100 X $\sigma_w^2/(\sigma_a^2 + \sigma_w^2)$.

4 %CV for length measurement = 100 X $\sigma_W/\bar{L}$ and for weight measurement = 100 X $\sigma_W/\bar{W}$.

5 σ_a = standard deviation among seals.

6 100 - %ME = % of total variance for seals = 100 X $\sigma^2_a/(\sigma^2_a + \sigma_w^2)$.

7 %CV for seal length = 100 X $\sigma/\bar{L}$ and weight = 100 X $\sigma_a/\bar{W}$.

(Fig. 8). Likewise, the difference in lengths was not significant ($P = 0.086$), but there may have been a tendency to get slightly longer lengths at the second measurement (Fig. 9). However, even if the average difference of 0.27 cm had been statistically significant, it is small relative to the 1 cm. increments in which measurements were recorded and the average pup length. The magnitude of measurement error in weight and length was not influenced by pup size (Table 12). Also, weight and length differences were not significantly correlated ($r = -0.12$, $P = 0.33$).

The difference between replicate measurements never exceeded 3 cm in length and 0.75 kg in weight (Figs. 10 and 11). The coefficient of variation (CV) of measurement error, a measure of precision relative to the sample mean, is less for length measurements (CV = 1.15%) than weight (CV = 1.95%). However, variation of weight among pups was greater (CV = 18.44%) than variation of length (CV = 5.69%). The greater variability in weight is reflected in the lower %ME for weight (1.11%) than length (3.95%). The small magnitude of %ME for both measurements demonstrates that measurement error is insignificant relative to among-pup variation.

The higher variability in weight may be associated with the feeding status of individual pups. From birth until weaning, fur seal pups undergo a cycle of nursing and fasting corresponding to their mother's cycle of feeding trips and time on land nursing her pup. Costa and Gentry (1986) estimated the mean milk intake for northern fur seal pups to be 2,650 and 4,270 ml/bout for

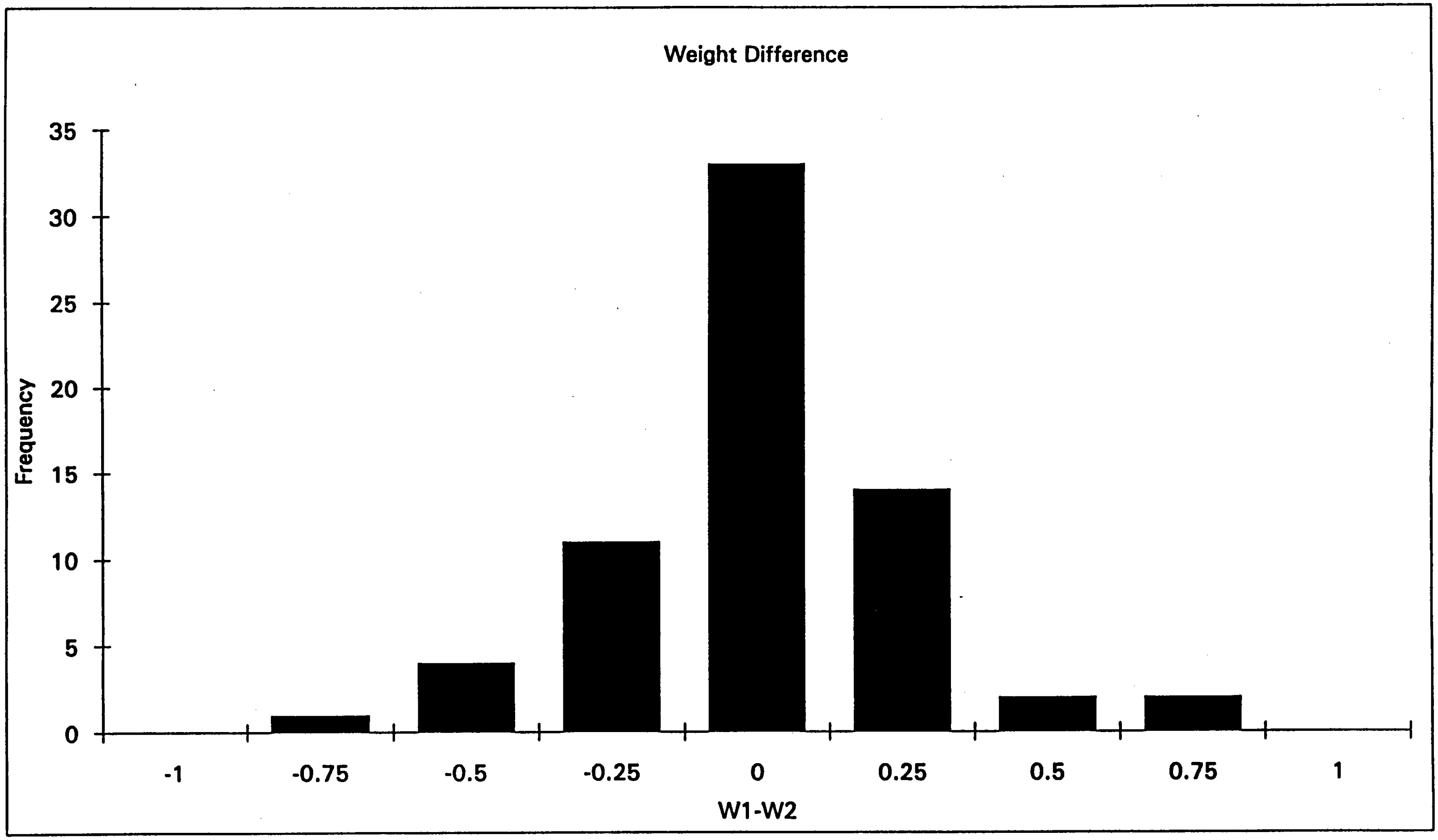

Figure 8. Frequency distribution of the difference between first and second weight measurements.

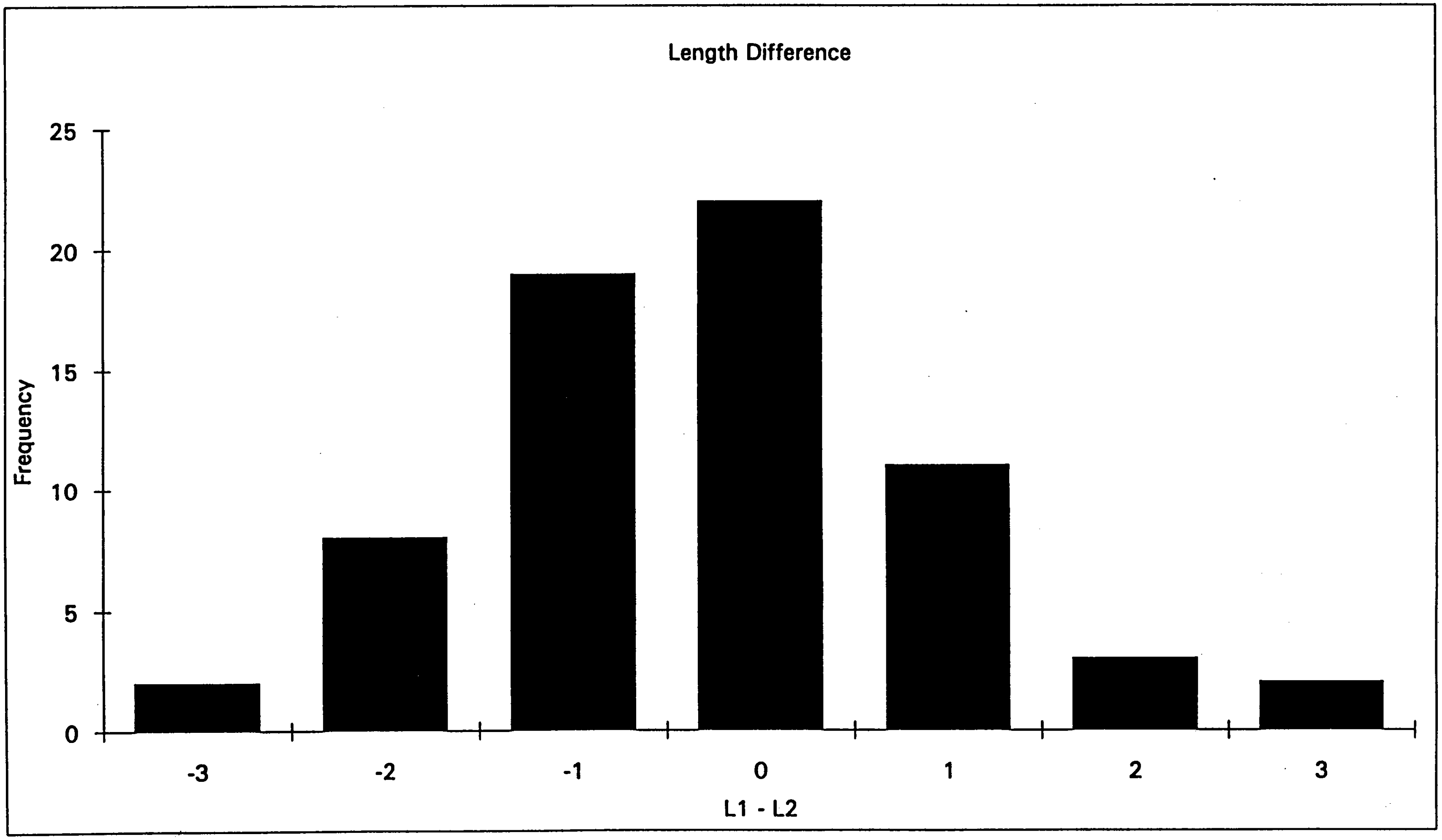

Figure 9. Frequency distribution of the difference between first and second length measurements.

Table 12.--Spearman rank correlation values (r_s) for absolute value of measurement differences and pup size as determined by average length and weight. In parentheses, the two-tailed probability from Student's *t*-distribution is given for the test that r_s=0.

Pup Size Determined by	Measurement Difference	
	Length	Weight
Length	0.036 (0.778)	-0.137 (0.280)
Weight	0.220 (0.081)	-0.086 (0.499)

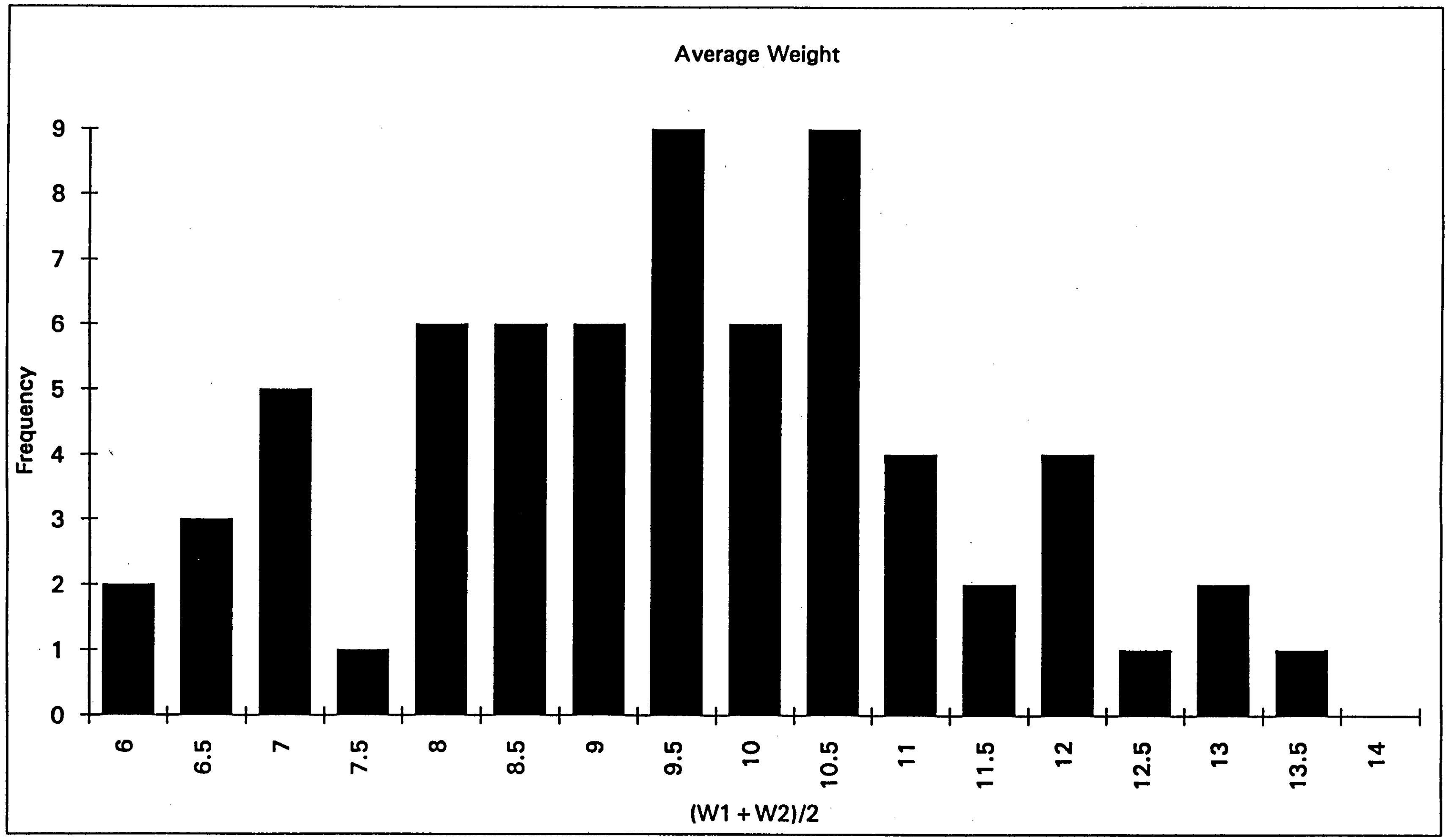

Figure 10. Frequency distribution of the average of replicate weight measurements.

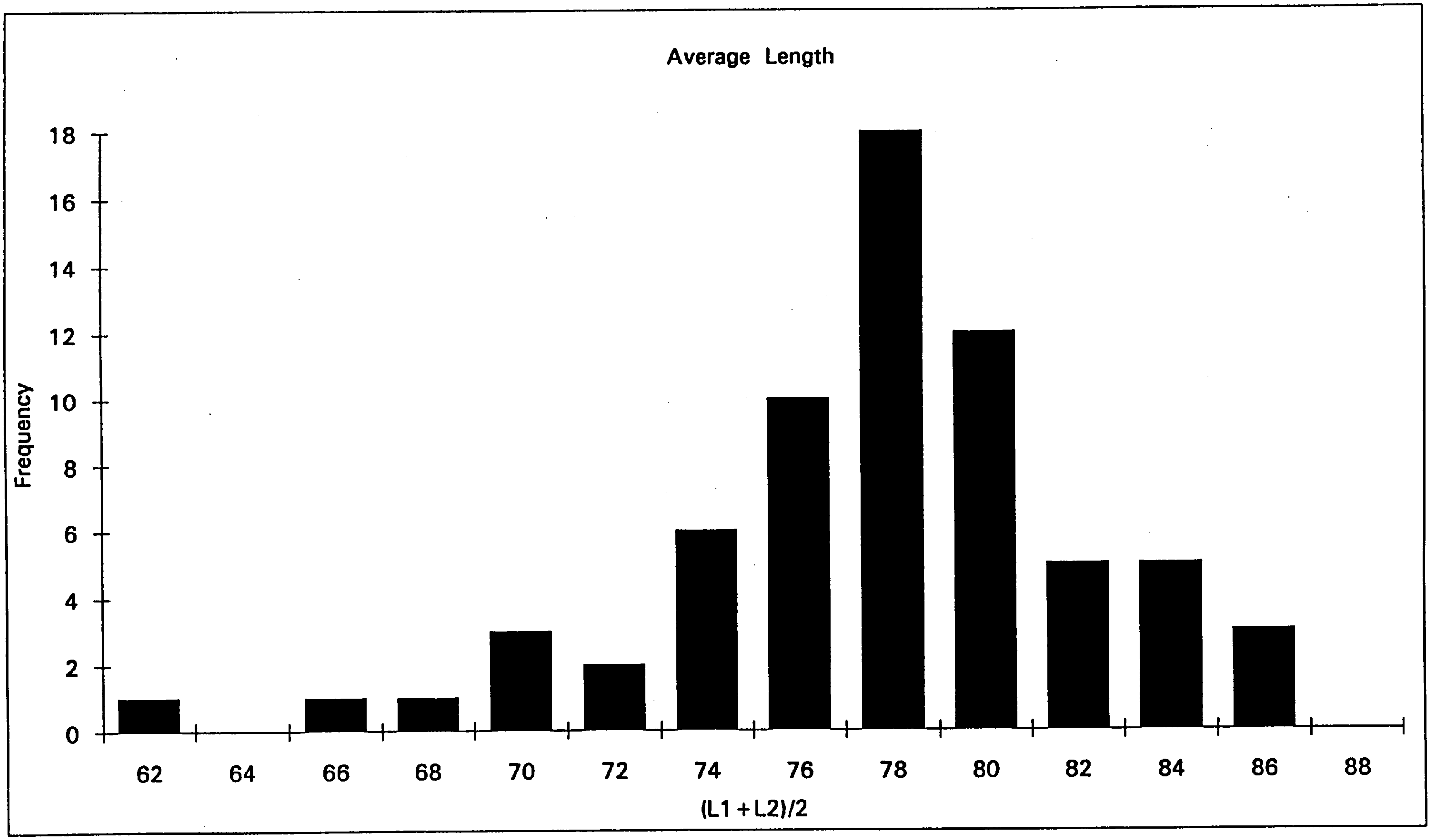

Figure 11. Frequency distribution of the average of replicate length measurements.

females and males, respectively. The weight of pups may vary according to whether the pup is nursing or fasting, which may affect the degree of short-term variability in weight measurements.

The low observed values for %ME demonstrate that measurement error for both length and weight is small relative to the total variation in the population. If data are collected in the same manner as was done in this study, measurement error does not exclude length data from consideration for use in the calculation of growth or condition indices for northern fur seal pups during the early stages of growth. However, there is some indication that as pups become larger, accurate length measurements may be more difficult to obtain. Although the relationship was not significant for this study, length measurements taken in the late season may be subject to higher %ME. It would be useful to collect repeat measurements on larger pups if length measurements are obtained during the late season in future studies.

POPULATION MONITORING STUDIES OF NORTHERN FUR SEALS AT SAN MIGUEL ISLAND, CALIFORNIA

by Sharon R. Melin, Robert L. DeLong, and James R. Thomason

Studies of the population dynamics of northern fur seals at San Miguel Island, California, have been conducted by researchers from the National Marine Mammal Laboratory since the discovery of the colony in 1968. Each year, counts of bulls and pups are conducted throughout the pupping and breeding season (May-August) to estimate trends in the population growth. In 1993, samples for an additional study to determine stock differentiation were collected.

METHODS

Observations of fur seals in Adams Cove began on 20 May and continued through 5 August 1993. Observations were made from two permanent blinds and one mobile blind. The mobile blind was only used late in July to minimize any potential disturbance to California sea lions (*Zalophus californianus*) which also pup and breed in Adams Cove.

Daily census' of the number of adult male fur seals (classes 2 and 3; see glossary in appendix A) were conducted from the fixed blinds. Live pup surveys were conducted on 22 July at Adams Cove and 29 July at Castle Rock. Surveys were conducted by three observers using binoculars and counting pups in each breeding group in Adams Cove. At Castle Rock, geographic markers served as boundaries for counting groups of pups until pups in late October, 280 pups were tagged with pink plastic roto tags at Adams Cove. An additional 10 pups sampled for genetic studies were tagged with plastic white roto tags at Adams Cove and 10 pups were tagged and sampled at Castle Rock. Samples consisted of a small piece of skin removed from a rear digit of each pup.

RESULTS AND DISCUSSION

Population Monitoring

In 1993, the first adult male arrived before 20 May. The maximum number of 102 territorial bulls occurred on 28 July in Adams Cove with 83 bulls holding territories with females and 19 bulls without females. The first birth in Adams Cove occurred on 8 June. A mean of 1,297 (SD = 4.2) live fur seal pups at Adams Cove and a mean of 750 (SD = 5.2) at Castle Rock is the largest number of pups counted at San Miguel Island since the colony was discovered.

Long-term studies of the population dynamics of the San Miguel fur seal population continued in 1993. Northern fur seal pups were tagged with pink plastic roto tags in September and October (Appendix Tables E 1-3). One hundred and forty-five pups were tagged in September at Adams Cove and 145 were tagged in October as a continuation of a study (initiated in 1988) on the effects of tagging relative to the age of the pup at tagging. At this time, sufficient data are not available to determine if a relationship exists.

Efforts to resight tagged fur seals were made throughout the summer at San Miguel Island. A total of 158 individuals were resighted. The greatest percentage of females were from the 1987 (10.7%) and 1988 (13.5%) cohorts (Table 13). The largest percentage of males (primarily juveniles and class 2 adult males) were from the 1988 (17.9%) and 1989 (17.4%) cohorts (Table 13).

Stock Differentiation

Tagging studies conducted in the early 1980s to evaluate the exchange between the Castle Rock and Adams Cove populations indicated that mixing of these populations was minimal (R. DeLong personal observation). In 1993, skin samples from 10 fur seal pups in Adams Cove and 10 pups at Castle Rock were collected for genetics studies to determine if the Castle Rock and the Adams Cove populations are distinct stocks of northern fur seals. This work is part of a long-term, collaborative study being conducted throughout the range of northern fur seals to determine the differentiation of stocks in Russia, Alaska, and California. The results from this study are not yet available.

Fur Seals and El Niño

The high pup count in 1993 is surprising since the El Niño conditions that began in January 1992 continued through the summer of 1993 and most likely reduced prey availability and abundance along the California, Oregon, and Washington coasts. This reduced prey availability during the winter and summer of 1993 was expected to reduce the productivity of female fur seals in 1993. However, females appeared healthy when they arrived at San Miguel Island just prior to parturition in June. The successful reproductive season suggests that females foraged

Table 13.--Tagged northern fur seal adults and juveniles sighted at San Miguel Island, May-August 1993.

Year tagged	Age at resighting	Total No. resighted	Percent males resighted	Percent females resighted
1976	17	1	---	0.9
1980	13	2	---	0.9
1981	12	2	---	0.9
1982	11	1	---	0.5
1984	9	2	4.2	---
1985	8	13	6.0	6.7
1986	7	10	4.1	5.9
1987	6	10	9.3	10.7
1988	5	61	17.9	13.5
1989	4	42	17.4	5.0
1990	3	11	8.8	1.2
1991	2	1	0.7	---
1992	1	2	---	1.2

efficiently and survived during the winter of 1993 before returning to the Southern California Bight during the pupping season.

Despite apparent successful foraging by females, pup weights remained low in 1993, similar to 1992 weights; the mean weight of males was 9.8 kg (SD = 1.9 kg) and the mean weight of females was 9.2 kg (SD = 1.6 kg) in 1993. These mean weights are significantly lower than weights ($P < .001$) in non-El Niño years (males, x = 11.8 kg, females, x = 10.4 kg) since 1970 (Delong and Antonelis 1991). El Nino events occurred in 1976, 1982-83, and 1992-1993 in the Southern California Bight where San Miguel Island is located. The low weaning weights observed in 1983, the strongest El Nino to occur in the last two decades, were a reflection of female foraging success during the pupping season. Females apparently had difficulty acquiring sufficient prey during the pupping season to provide for normal pup growth (DeLong and Antonelis 1991).

Although pup production was high in 1993, the lower weaning weights of pups may compromise their survival in the first year, particularly if prey availability is low during the winter months of 1994 (Calambokidis and Gentry 1985, Baker and Fowler 1992). Since the pups will not return to San Miguel Island until they are 2 or 3 years of age, the effect of the 1992-93 El Niño on survival of pups and juveniles can not be fully evaluated until the cohort returns to San Miguel Island in 1995 or 1996.

Although the San Miguel Island fur seal population has exhibited dramatic fluctuations in the past 20 years, primarily due to El Niño events, it continues to increase slowly and steadily (Delong and Antonelis 1991). The monitoring studies at San Miguel Island provide information on the dynamics of a fur seal population that is often confronted with highly variable environmental conditions. Density-independent mechanisms (El Niño events) may be the most important factors regulating this population.

CENSUS OF NORTHERN FUR SEALS
ON BOGOSLOF ISLAND, ALASKA, 1993

by

Rolf R. Ream and Rodney G. Towell

Northern fur seals on Bogoslof Island, Alaska, were counted on 23 August 1993. This was the first census since 1990, and more significantly, since the northeast end of the island experienced substantial volcanic activity during July 1992.

METHODS

Northern fur seals were counted directly while walking next to or through all rookeries and haul-out areas on the island. The distribution of rookeries on Bogoslof Island are shown in Figure 4. Independent counts of pups were made by no less than two and up to four different researchers and the counts were averaged for each rookery area. One count of females, territorial males, and subadult males was made on the sand spit at the southern end of the island and at the adjacent rookery area. In all other areas, counts were categorized as pups and non-pups (1 year of age or older) due to insufficient time and because intermixture of immature males and females on the rookeries made it difficult to accurately differentiate various age and sex categories.

RESULTS

A total of 5,544 fur seals were counted on Bogoslof Island on 23 August 1993, including 890 live pups, 8 dead pups, and 4,646 non-pups (females, adult males, and subadult males; Table

14). One hundred forty-one females and 42 adult territorial males with females were observed at the southern rookery. One dead male and two dead females were seen in the rookery areas and are not included in the counts or in Table 14.

The results of the 1993 census indicate an increase in the population of northern fur seals on Bogoslof Island. Counts made on 24 July 1990 yielded a total of 1,473 fur seals, including 181 live pups, 2 dead pups, and 1,290 non-pups (Baker and Kiyota 1992). From 1990 to 1993, the total number of northern fur seals increased by 276.4%, or 4,071 individuals, and the number of pups born increased by 390.7%, or 715 individuals.

Other Observations

Eleven entangled animals were observed, nine of which were assumed to be females due to their location relative to the rookery areas. One entangled female was captured and the debris (blue and black seine net) was removed. At least seven monel-tagged individuals were sighted (all sex and age categories combined). However, no tag numbers were obtained.

Four adult harbor seals (Phoca vitulina) were counted on the beach on the east side of Bogoslof Island. These animals were hauled out among Steller sea lions (Eumetopias jubatus) and subadult male northern fur seals south of the rookery on the northeast side of the island. Steller sea lions were not counted.

Prior to landing on the island, five killer whales (Orcinus orca) were observed surrounding and preying on a subadult male northern fur seal (approximately 4 to 5 years of age).

Table 14.--Numbers of northern fur seals counted on 23 August 1993 at Bogoslof Island, Alaska.

	Northwest side	Northeast side	South side	Total
Live pups	592	143	155	890
Dead pups	4	0	4	8
Territorial males			42*	
Females			141*	
Non-territorial males			1444*	
Total, non-pup	2228	791	1627	4646
Total	2824	934	1786	5544

*included in the "Total, non-pup" category.

Volcanic activity at Bogoslof Island began on 6 July 1992. Steam and ash emissions continued at least through 24 July at times reaching altitudes of up to 26,000 ft (Neal and McGimsey 1992). The activity enlarged the northeast end of the island significantly (Fig. 4). A new lava dome approximately as high as Castle Rock (330 ft) was formed and was still emanating steam at the time of the survey. Some large boulders on the slopes of the new dome were covered with dead barnacles. An extensive kelp bed which had been on the east side of the island was no longer present. Rock and dirt were apparently displaced toward the grassy saddle between Kenyon Dome and Puffin Slope, covering most of the area where the northeast fur seal rookery previously existed. Evidence of fur seal fatalities in this area exists by means of partially buried carcasses (skeleton and some skin remains). Two of the carcasses examined had fractured skulls.

Despite the volcanic activity and any resulting fatalities, the Bogoslof Island northern fur seal population has experienced substantial growth. The distribution of animals has expanded to include much of the accessible beach. The rookery areas have increased in size while remaining as three distinct groups in approximately the same locations.

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APPENDIX A

Glossary

The following terms used in fur seal research and management on the Pribilof Islands, Bogoslof Island, San Miguel Island, and Castle Rock have special meanings or are not readily found in standard dictionaries.

Bachelor	Young male seals of age 2-5 years.

<u>Classifications of adult male fur seals</u>

Class 1 (shoreline)	Full-grown males apparently attached to "territories" spaced along the water's edge at intervals of 10-15 m. Most of these animals are wet or partly wet, and some acquire harems of one to four females between 10 and 20 July. They would then be called harem males (Class 3). Class 1 males should not be confused with Class 2 animals, which have definite territories, whereas the shoreline males appear to be attached to such sites but may not be in all cases.
Class 2 (territorial without females)	Full-grown males that have no females, but are actively defending territories. Most of these animals are located on the inland fringe of a rookery: some are between Class 1 (shoreline) and Class 3 (territorial with females) males, and a few are completely surrounded by Class 3 males and their harems.
Class 3 (territorial with females)	Full-grown males actively defending territories and females. Most Class 3 males and their harems combine to form a compact mass of animals. Isolated individuals, usually with small harems, may be observed at each end of a rookery, on sandy beaches, and in corridors leading to inland hauling grounds. Some territorial males have as few as one or two females. Should these females be absent during the counts, their pups are used as a basis for putting the adult male into Class 3 rather than Class 2.

Class 4 (back fringe)	Full- and partly grown males on the inland fringe of a rookery. A few animals too young and too small to include in the count may be found here. Though some Class 4 males may appear to be holding territories, most will flee when approached or when prodded with a pole.
Class 5 (hauling ground)	The hauling grounds contain males from May to late July and a mixture of males and females from then on. The counts include males that obviously are adults and all others that have a mane and the body conformation of an adult. Males included in this count are approximately 7 years of age and older. Prior to 1966, Class 3 males were called harem bulls, and Classes 1,2,4, and 5 were collectively called idle bulls. From 1966 through 1974, the adult male seals were classified into five groups (Classes 1, 2, 3, 4, and 5). Beginning in 1975, Classes 1 and 2 were combined and designated as Class 2, Class 3 remained the same, and Classes 4 and 5 were combined and designated as Class 5.
Drive	The act of surrounding and moving groups of seals from one location to another.
Hauling ground	An area, usually near a rookery, on which nonbreeding seals congregate. See Rookery.
Haul out	The act of seals moving from the sea onto shore at either a rookery or hauling ground.
Kleptogyny	The act of an adult male seal (primarily classes 1, 2, or 3) seizing an adult female from another male's territory.
Known-age	Refers to a seal whose age is known because the animal bears an inscribed tag or other type of mark.

Marked	Describes a seal that has been marked by attaching an inscribed metal or plastic tag to one or more of its flippers, by hair clipping, or by bleaching.
Mark recoveries	Recovery (sighting) of a seal that has been marked by one of several methods. See marked.
Rookery	An area on which breeding seals congregate. See Hauling ground.
Roundup	Biologists surround and herd juvenile male fur seals close to the location they haul out.
Vibrissae (facial whiskers)	To determine the relative age structure of females in a population, the color of their whiskers are used. Facial vibrissae are black at birth and remain black through age 3 years; become mixed (black and white) at ages 4 and 5 years; and by age 7, the vibrissae usually are entirely white.

APPENDIX B

Tabulations of adult male northern fur seals counted by rookery, size class, and rookery section.

Appendix Table B-1.--Number of adult male northern fur seals counted, by rookery, Pribilof Islands, Alaska, July 1993.

Rookery	Date (July)	Class of adult male[a] 2	3	5	Total
St. Paul Island					
Lukanin	11	43	160	180	383
Kitovi	11	96	321	372	789
Reef	13	181	770	1050	2001
Gorbatch	13	149	546	1105	1800
Ardiguin	13	28	96	15	139
Morjovi	18	139	508	499	1146
Vostochni	18	286	1129	992	2407
Little Polovina	12	8	18	366	392
Polovina	12	40	80	240	360
Polovina Cliffs	12	146	604	278	1028
Tolstoi	17	255	760	523	1538
Zapadni Reef	15	83	243	320	646
Little Zapadni	15	124	450	487	1061
Zapadni	14	244	720	1052	2016
Island total		1822	6405	7479	15706
St. George Island					
Zapadi	9	50	138	188	376
South	9	90	218	78	386
North	9/10	204	429	217	850
East Reef	8	57	37	63	157
East Cliffs	8	110	230	199	539
Staraya Artil	12	71	71	95	237
Island total		582	1123	840	2545

[a] See glossary for a description of the classes of adult male seals.

Appendix Table B-2.--Number of harem and idle male northern fur seals counted in mid-July, Pribilof Islands, Alaska, 1984-93.

Year	St. Paul Island		St. George Island		Total	
	Harem	Idle	Harem	Idle	Harem	Idle
1984	4,803	3,977	1,473	1,452	6,276	5,429
1985	4,372	3,363	1,286	1,601	5,658	4,964
1986	4,603	1,865	1,394	1,342	5,997	3,207
1987	3,636	1,892	1,303	1,283	4,939	3,175
1988	3,585	3,201	1,259	1,258	4,844	4,459
1989	4,297	6,400	1,241	1,163	5,538	7,563
1990	4,430	7,632	909	1,666	5,339	9,298
1991	4,729	9,543	736	1,271	5,465	10,814
1992	5,460	10,940	1,028	1,834	6,488	12,774
1993	6,405	9,301	1,123	1,422	7,528	10,723

Appendix Table B-3.--Number of adult male northern fur seals counted, by class[a] and rookery section, St. Paul Island, Alaska, 11-18 July 1993. A dash indicates no section.

Rookery and class of male	Section 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Lukanin															
2	26	17	-	-	-	-	-	-	-	-	-	-	-	-	43
3	86	74	-	-	-	-	-	-	-	-	-	-	-	-	160
5	168	12	-	-	-	-	-	-	-	-	-	-	-	-	180
Kitovi[b]															
2	17(9)	11	23	19	17	-	-	-	-	-	-	-	-	-	96
3	40(21)	12	63	109	76	-	-	-	-	-	-	-	-	-	321
5	71(83)	5	16	5	192	-	-	-	-	-	-	-	-	-	372
Reef															
2	20	19	25	23	18	22	8	15	16	13	2	-	-	-	181
3	105	96	101	90	64	105	18	85	62	39	5	-	-	-	770
5	32	23	104	66	206	0	177	91	16	141	194	-	-	-	1050
Gorbatch															
2	41	27	31	0	23	27	-	-	-	-	-	-	-	-	149
3	155	112	97	0	78	104	-	-	-	-	-	-	-	-	546
5	636	35	94	257	21	62	-	-	-	-	-	-	-	-	1105
Ardiguen															
2	28	-	-	-	-	-	-	-	-	-	-	-	-	-	28
3	96	-	-	-	-	-	-	-	-	-	-	-	-	-	96
5	15	-	-	-	-	-	-	-	-	-	-	-	-	-	15
Morjovi[c]															
2	11(9)	15	27	21	33	23	-	-	-	-	-	-	-	-	139
3	43(33)	84	82	67	129	70		-	-	-	-	-	-	-	508
5	117(69)	45	97	25	51	95	-	-	-	-	-	-	-	-	499
Vostochni															
2	11	13	15	17	15	45	20	20	11	5	11	28	46	29	286
3	49	28	73	61	60	135	75	99	56	38	44	89	206	116	1129
5	51	56	14	99	128	108	41	28	47	11	4	121	135	149	992
Little Polovina															
2	8	-	-	-	-	-	-	-	-	-	-	-	-	-	8
3	18	-	-	-	-	-	-	-	-	-	-	-	-	-	18
5	366	-	-	-	-	-	-	-	-	-	-	-	-	-	366
Polovina															
2	21	19	-	-	-	-	-	-	-	-	-	-	-	-	40
3	51	29	-	-	-	-	-	-	-	-	-	-	-	-	80
5	151	89	-	-	-	-	-	-	-	-	-	-	-	-	240
Polovina Cliffs															
2	21	16	15	13	24	15	42	-	-	-	-	-	-	-	146
3	56	56	41	86	121	77	167	-	-	-	-	-	-	-	604
5	32	30	27	32	56	62	39	-	-	-	-	-	-	-	278
Tolstoi															
2	20	16	28	17	51	40	44	39	-	-	-	-	-	-	255
3	75	65	87	90	86	153	119	85	-	-	-	-	-	-	760
5	9	11	20	33	16	32	25	377	-	-	-	-	-	-	523
Zapadni Reef															
2	71	12	-	-	-	-	-	-	-	-	-	-	-	-	83
3	174	69	-	-	-	-	-	-	-	-	-	-	-	-	243
5	142	178	-	-	-	-	-	-	-	-	-	-	-	-	320
Little Zapadni															
2	5	18	22	25	28	26	-	-	-	-	-	-	-	-	124
3	18	57	104	96	76	99	-	-	-	-	-	-	-	-	450
5	35	29	30	26	65	302	-	-	-	-	-	-	-	-	487
Zapadni[d]															
2	11(0)	26	34	54	35	47	30	7	-	-	-	-	-	-	244
3	61(0)	98	103	115	85	133	111	14	-	-	-	-	-	-	720
5	37(213)	29	69	97	135	56	52	364	-	-	-	-	-	-	1052

[a] See Glossary for a description of the classes of adult males seals.
[b] Numbers in parentheses are the adult males counted in Kitovi Amphitheater.
[c] Numbers in parentheses are the adult males counted on the second point south of Sea Lion Neck.
[d] Numbers in parentheses are the adult males counted on Zapadni Point Reef.

APPENDIX C

by

Anne E. York

The Jolly-Seber model for estimating survival rates of male northern fur seals from tag resights of juvenile males.

In this appendix, I present the details of the Jolly-Seber model for estimating survival rates of male northern fur seals from resighting information taken during roundups of tagged males on the hauling grounds. It is assumed that fur seals will be tagged as pups (age 0) and will be available for resighting at age(s) 2, 3, 4, and 5 years. From the estimates of the variances of the parameters, I derive approximations of sample sizes required to achieve a particular precision.

The following parameters are defined ("animals" are assumed to be tagged males):

N: number of animals marked,

M_i: number of marked animals alive at age i, i= 2, 3, 4, and 5,

Φ_0: Pr(animal is alive at age 2 years),

Φ_i : Pr(animal alive at age i+1| alive at age i), i=2, 3, 4, and 5,

p_i : Pr(animal is sighted at age i |alive at age i), i=2, 3, 4, and 5,

x_i : Pr(animal not sighted after i |alive at age i), i=0, 2, 3, 4, and 5.

Given that an fur seal is alive at age i, it will not be sighted after age i if one of the following conditions holds: 1) it dies between age i and i+1; or 2) it survives to age i+1, is not captured at age i+1, and is not sighted after age i+1. Thus, the x_i can be back calculated from the following formulae (Cormack 1982):

$$(1)\qquad x_i = \begin{cases} 1 - \Phi_0 + \Phi_0(1-p_2)x_2 & i=0 \\ 1 - \Phi_i + \Phi_i(1-p_{i+1})x_{i+1} & i=2,3,4 \\ 1 & i=5 \end{cases}$$

In the following, assume that if the i^{th} subscript is a 1, the fur seal is sighted at age i+1; if it is a 0, the fur seal is not sighted at age i+1; for example the subscript 1111 means the fur seal was sighted at age 2, 3, 4, and 5; the subscript 0100 means the fur seal was sighed only at age 3. Our study attempts sightings in 4 different years; thus, there are 2^4=16 distinct capture histories. The following are the expected values of the possible capture histories if resighting effort in each year is the same:

1: $E[h_{1111}] = N\Phi_0\Phi_2\Phi_3\Phi_4 p_2 p_3 p_4 p_5$

2: $E[h_{0111}] = N\Phi_0\Phi_2\Phi_3\Phi_4(1-p_2)p_3 p_4 p_5$

3: $E[h_{1011}] = N\Phi_0\Phi_2\Phi_3\Phi_4 p_2(1-p_3)p_4 p_5$

4: $E[h_{0011}] = N\Phi_0\Phi_2\Phi_3\Phi_4(1-p_2)(1-p_3)p_4 p_5$

5: $E[h_{1101}] = N\Phi_0\Phi_2\Phi_3\Phi_4 p_2 p_3(1-p_4)p_5$

6: $E[h_{0101}] = N\Phi_0\Phi_2\Phi_3\Phi_4(1-p_2)p_3(1-p_4)p_5$

7: $E[h_{1001}] = N\Phi_0\Phi_2\Phi_3\Phi_4 p_2(1-p_3)(1-p_4)p_5$

8: $E[h_{0001}] = N\Phi_0\Phi_2\Phi_3\Phi_4(1-p_2)(1-p_3)(1-p_4)p_5$

9: $E[h_{1110}] = N\Phi_0\Phi_2\Phi_3 p_2 p_3 p_4 x_4$

10: $E[h_{0110}] = N\Phi_0\Phi_2\Phi_3(1-p_2)p_3 p_4 x_4$

11: $E[h_{1010}] = N\Phi_0\Phi_2\Phi_3 p_2(1-p_3)p_4 x_4$

12: $E[h_{0010}] = N\Phi_0\Phi_2\Phi_3(1-p_2)(1-p_3)p_4 x_4$

13: $E[h_{1100}] = N\Phi_0\Phi_2 p_2 p_3 x_3$

14: $E[h_{0100}] = N\Phi_0\Phi_2(1-p_2)p_3 x_3$

15: $E[h_{1000}] = N\Phi_0 p_2 x_2$

16: $E[h_{0000}] = N x_0$

If effort is known and varies, then the above equations change slightly. Suppose that relative to the effort at age 2, effort for fur seals age i is e_i, then substitute e_i p_i for p_i ($i > 2$) in the above equations.

All 16 capture histories are observable since N, the number of males marked as pups, is known. In many applications of the J-S method, N is not known, and thus, the 16th capture history is not observed. In this development, it assumed that effort is equal at each capture opportunity. If it is not, it may be possible to adjust the estimates for effort if the effort is known. Suppose that relative to effort at age 2, the effort at age i (i = 3-5) is e_i, ie. $e_2 = 1$. Then the expectations can be adjusted by replacing p_i by $p_i\ e_i$. It is important to do this if p_i is to have the interpretation we assumed for it.

Define the following, assuming that the definitions apply to a single cohort:

m_i = number of marked fur seals sighted at age i= 2, 3, 4, and 5.

z_i = number of marked fur seals sighted before the ith sample, not sighted in the ith sample but sighted subsequently, i = 2, 3, 4, and 5.

r_i = number of marked fur seals sighted at age i and subsequently resighted at age i+1, i+2 ..., 5.

If all animals have the same capture probabilities at each age i, and if capture at age i does not affect the likelihood of subsequent recapture, then:

(2) $E[m_i] = p_i M_i$ and $E[r_i] = m_i(1 - x_i)$

Assuming no losses on capture, i.e. all sighted animals are returned to the population, the Jolly-Seber estimates of the number of marked fur seals alive at age are (Seber 1982):

$$\hat{M}_i = m_i(1 + \frac{z_i}{r_i}) \text{ for } i = 2,3,\text{or},4$$

Estimates of survival are the following:

$$\hat{\Phi}_0 = \frac{\hat{M}_2}{N},\ \hat{\Phi}_2 = \frac{\hat{M}_3}{\hat{M}_2},\ \text{and},\ \hat{\Phi}_3 = \frac{\hat{M}_4}{\hat{M}_3}.$$

The asymptotic variance of the survival estimates can be derived from the following (Pollock 1981):

$$(3) \qquad Var[\hat{M}_i] = M_i(M_i - E[m_i]) \left(\frac{1}{E[r_i] - \frac{1}{m_i}} \right)$$

The variance of $\hat{\Phi}_0$ is:

$$(4) \qquad Var[\hat{\Phi}_0] = Var[\frac{\hat{M}_2}{N}] = \frac{1}{N^2} Var[\hat{M}_2]$$

Substituting (3) into (4) and using (1) and (2):

$$(5) \qquad N^2 Var[\hat{\Phi}_0] = Var[\hat{M}_2] = \frac{M_2^2(1-p_2)x_2}{m_2(1-x_2)}$$
$$= \frac{(\Phi_0 N)^2(1-p_2)x_2}{m2\,(1-x2)}$$
$$= \frac{k}{m_2}, \text{ where } k = \frac{\Phi_0 N^2(1-p_2)x_2}{1-x_2}$$

Assume m_2 is a binomial (M_2, p_2) random variable, and recall that $E(m_2) = p_2 M_2$ and

$Var(m_2)= M_2\, p_2\, (1-p_2)$. Applying the delta method to (5):

$$(6)\qquad E[\frac{k}{m_2}] \approx \frac{k}{E[m_2]} + .5\, Var\,[m_2] \frac{\partial^2}{\partial m_2^{\,2}} \frac{k}{m_2}\Big|_{E[m_2]}$$
$$= \frac{k}{E[m_2]} + \frac{k\, Var\,[m_2]}{E^3[m_2]}$$
$$= \frac{k}{E[m_2]}(1 + \frac{Var\,[m_2]}{E^2[m_2]})$$
$$= \frac{k}{p_2 M_2}(1 + \frac{M_2 p_2 (1-p_2)}{(p_2 M_2)^2})$$
$$= \frac{k}{p_2 M_2}(1 + \frac{1-p_2}{p_2 M_2})$$

Noting that $M_2 = s\,N$ and substituting k from (5) into (6),

$$(7)\qquad Var(\hat{\Phi}_0) = \frac{1}{N^2} Var\,[\frac{k}{m_2}] \approx \frac{\Phi_0 (1-p_2) x_2}{N\, p_2 (1-x_2)} (1 + \frac{1-p_2}{p_2\, \Phi_0 N})$$

This expected variance can be thought of as a product of s/N with two conditional (on being alive at age 2) odds ratios and a correction factor. The first odds ratio ($or_1=(1-p_2)/p_2$) is that of not being sighted at age 2 versus being sighted at age 2 and the second odds ratio ($or_2= x_2)/(1-x_2)$ is that of being sighted after age 2 versus never being sighted after age 2. The correction factor is very nearly one if the number of marked fur seals that are alive at age 2 (Φ_0 N) is much larger than or_1. It is also important to note that the variance estimate for Φ_0 is conditioned on Φ_0; the unconditional variance is calculated by adding $\Phi_0\, (1-\Phi_0\,)/M_2$. This term will be ignored since for moderate sample size, it is very small.

The restriction of the estimation to obtain a single estimate of average survival from ages 2 - 5 years is possible numerically in program SURVIVE (White

1992).

In addition, I note that the survival from the time of tagging to age i can be estimated as Mi/N and its expected variance can be approximated using (7), with p_2 replaced by p_i, x_2 replaced by x_i, and $\hat{p}$ by the estimated survival to age i.

The variance of Φ_i (i=2 and 3) is calculated in the following way (Pollock 1981) (recall that all marked fur seals are returned to the population):

$$Var[\hat{\Phi}_i] \approx \Phi_i^2 \{ (\frac{M_{i+1} - E[m_{i+1}]}{M_{i+1}}) (\frac{1}{E[r_{i+1}]} - \frac{1}{m_{i+1}}) + \frac{(M_i - E[m_i]}{M_i}) (\frac{1}{E[r_i]} - \frac{1}{m_i}) \}$$

None of the above estimates account for tag loss. To estimate the number of fur seals from the original marked population that are alive at age i, we must adjust both the estimate and its variance for double tag loss. Since fur seals are to be double tagged, we can observe the rate of single tag loss (if tag loss is independent of sighting probability); if we assume that tags behave independently, we can estimate double tag loss as the square of the single tag loss rate. Because there are no available data on the rate of tag loss of the new tag, the assumptions made for this derivation will be simple.

Let t_i be probability that an fur seal alive at age i has lost both tags, and t_i, $Var(t_i)$ be the its variance and $\hat{t}_i$, its estimate. Then estimates of survival adjusted for tag loss are:

$$\hat{\Phi}_0^* = \frac{\hat{\Phi}_0}{1 - \hat{t}_2} \quad \text{and} \quad \hat{\Phi}_i^* = \frac{\hat{\Phi}_i}{1 - \hat{t}_i}$$

Estimates of the expectations and variances of these adjusted survival rates can be made using the delta method. Assuming that the covariance between survival and tag-loss is 0:

$$E[\hat{\Phi}^*_0] \approx \frac{\Phi_0}{1-t_2} + \frac{\Phi_0 Var[t_2]}{(1-t_2)^3}$$

$$(8) \qquad Var[\Phi^*_0] \approx (\frac{\Phi_0}{1-t_2})^2 (\frac{Var[\hat{\Phi}^*_0]}{\Phi_0^2} + \frac{Var[t_2]}{(1-t_2)^2})$$

Assuming that the number of fur seals with double tag loss at age i is distributed as binomial (M_i,t_i), where M_i is the number alive at age i. Then,

$$(9) \qquad Var[t_i] = \frac{t_i(1-t_i)}{M_i} \text{ and therefore },$$

Substituting (9) into (8),

$$(10) \qquad Var[\hat{\Phi}^*_0] = \frac{1}{(1-t_2)^2} (Var[\hat{\Phi}_)] + \frac{\Phi\, t_2}{M_2(1-t_2)})$$

Combining (10) and (7):

$$(11) \qquad Var[\hat{\Phi}^*_)] \approx \{\frac{\Phi_0}{N(1-t_2)^2})\} \{ \frac{(1-p_2)x_2}{p_2(1-\chi_2))} (1 + \frac{1-p_2}{\Phi_0 p_2 N}) + \frac{\Phi_0^2 t_2}{N s p_2(1-t_2)} \}$$

The estimated sample size required for fixing the estimated variance at level, v, is obtained by solving (11) set to v for N; solutions of this equation are easily calculated since (11) is quadratic in N for fixed v, Φ_0, t_2, and p_2.

This is not the only way of adjusting for tag-loss. Another way is to include tag-loss parameters in the Jolly-Seber model. If q_0 is the probability that a tag survives from tagging to age 2, and q_i is the probability that a tag survives from period i-1 to i, i=2,5 (observation period 1 corresponds to time of tagging), a Jolly-Seber model can be developed which incorporates expected numbers of single tagged and double tagged fur seals sighted. In this way, it may be possible to determine if the sighting probability is higher for fur seals with no lost tags than those with one lost tag.

APPENDIX D

by

Bruce W. Robson and Charles W. Fowler

Removal of Debris From Entangled Seals.

During research activities on St. George and St. Paul Island, when time and circumstances allowed, entangled seals were captured and debris was removed. A total of 34 males were disentangled on St. Paul Island and 9 males and 1 female were disentangled on St.George Island. Information on seals captured, debris removed, location, and activity are summarized in Appendix Table D-1. Allflex tags were applied to all juvenile males of the size counted in the entanglement study roundups (ages 2-4).

An effort to capture and remove debris from entangled seals during the subsistance harvests was undertaken in cooperation with Aleut community members on both islands. Ten male seals were disentangled at the St. Paul harvest and 2 males on St. George.

An entangled adult female was captured at Zapadni rookery on St. George using a portable observation blind. The debris was removed and she was released in the territory in which she was captured. This technique resulted in minimal disturbance to the rookery and could be utilized in suitable terrain on both islands.

Appendix Table D-1.-- Opportunistic disentanglements of northern fur seals during research activities on St. Paul, St. George, and Bogoslof Islands.

Date	Location	Sex	Size/Age	Tagged	Comments
ST. PAUL					
7/14	Zapadni	Male	juvenile	yes	bull counts; green trawl webbing, applied brd. white Allflex no. 1490
7/14	Zapadni	Male	juvenile	yes	bull counts; green trawl webbing, applied brd. white Allflex no. 1491
7/14	Zapadni	Male	juvenile	yes	bull counts; yellow plastic packing band, applied brd. white Allflex no. 1490
7/14	Zapadni	Male	subadult	no	bull counts; green trawl webbing
7/14	Zapadni	Male	subadult	no	bull counts; blue plastic packing band
7/15	Little Zapadni	Male	3-yr-old	yes*	bull counts; yellow plastic packing band, *Monel tag no. A20264, both present
7/15	Vostochni	Male	juvenile	no	disentangled in conjunction with deployment of photo-electric light recorders; green trawl webbing, juvenile, no wound, not tagged
7/16	Reef	Male	?	no	harvest
7/17	Tolstoi	Male	subadult	no	bull counts; white plastic packing band
7/17	Tolstoi	Male	juvenile	yes	bull counts; brown plastic string, applied brd. white Allflex no. 1493
7/18	Morjovi	Male	subadult	no	bull counts; monofilament line
7/18	Morjovi	Male	subadult	no	bull counts; yellow plastic packing band
7/18	Morjovi	Male	juvenile	yes	bull counts; green-grey trawl webbing, applied brd. white Allflex no. 1495
7/18	Vostochni	Male	subadult	no	bull counts; grey trawl
7/18	Vostochni	Male	juvenile	yes	bull counts; white plastic packing band, applied brd. white Allflex no. 1497
7/18	Vostochni	Male	juvenile	yes	bull counts; blue plastic packing band, applied brd. white Allflex no. 1498

Appendix Table D-1.-- Continued.

Date	Location	Sex	Size/Age	Tagged	Comments
7/24	Zapadni	Male	juvenile?	yes?	harvest; orange trawl webbing, very tight, 360 degree wound, applied either brd. white Allflex no. 1496 or no. 1499
7/29	Morjovi	Male	juvenile	yes	harvest; applied brd. white Allflex no. 32
7/31	Reef	Male	juvenile	yes	harvest; lead line rope, no wound, applied brd. white Allflex no. 33
7/31	Reef	Male	juvenile	yes	harvest; applied brd. white Allflex no. 34
8/2	Polovina	Male	juvenile	yes	harvest; white plastic packing band, loose, no wound, applied brd. white Allflex no. 35
8/3	Zapadni Reef	Male	subadult	no	harvest; trawl webbing, 360 degree wound
8/5	Zapadni	Male	juvenile	yes	harvest; yellow poly. rope, loose, no wound, applied brd. white Allflex no. 36
8/5	Zapadni	Male	juvenile	yes	harvest; white plastic packing band, loose, no wound, applied brd. white Allflex no. 37
8/6	Reef	Male	subadult	no	harvest; yellow plastic packing band;
8/11	Vostochni	Male	juvenile	yes*	scat collection; green poly. rope, very tight, 360 degree wound, *Monel tag no. 21616, both present
8/11	Vostochni	Male	juvenile	yes	scat collection; blue poly. rope, loose, no wound, applied brd. blue Allflex no. 1689
8/11	Polovina	Male	juvenile	yes	scat collection; red plastic ring, loose, no wound, applied brd. blue Allflex no. 1690
8/11	Polovina	Male	juvenile	yes	scat collection; blue trawl webbing, tight, 90 degree wound, applied brd. blue Allflex no. 1702 (one side may have mistakenly been tagged with no. 1703)
8/11	Polovina	Male	subadult	no	scat collection; grey trawl
8/11	Reef	Male	juvenile	yes	scat collection; blue plastic packing band, loose, no wound, applied brd. blue Allflex no. 1710
8/11	Reef	Male	subadult	no	scat collection; blue trawl webbing, very tight, 180 degree wound
8/11	Gorbatch	Male	juvenile	yes	scat collection; clear plastic packing band, 90 degree wound, applied brd. blue Allflex no. 1704

Appendix Table D-1.-- Continued.

Date	Location	Sex	Size/Age	Tagged	Comments
8/11	Zapadni	Male	juvenile	yes	scat collection; blue plastic packing band, very tight, deep 360 degree wound, applied brd. blue Allflex no. 1705 left, no. 1706 right
ST. GEORGE					
7/8	East Reef	Male	juvenile	yes*	bull count; trawl webbing, *Monel tag no. A17558, both present
7/8	East Reef	Male	juvenile	yes	bull count; grey trawl webbing, tight, 360 degree wound, applied brd. blue Allflex no. 1661
7/10	Zapadni	Male	juvenile	yes	harvest; grey trawl, loose, no wound, applied brd. blue Allflex no. 1662
7/10	Zapadni	Female	--------	no	box; grey trawl webbing, tight, 90 degree wound
7/12	Zapadni	Male	subadult	no	bull count; grey trawl (approx. 300grams, tight, 260 degree wound
7/12	Zapadni	Male	subadult	no	bull count; brown twine, tight, 90 degree wound
7/12	Zapadni	Male	subadult	no	bull count; black codend webbing with attached rope approx. 2 kg, very tight, severe 360 degree wound
7/15	North	Male	subadult	no	harvest; grey trawl webbing, tight, 90 degree wound
BOGOSLOF					
8/23	Bogoslof	Female	-	no	population census; blue and black webbing (seine?) tight, 90 degree wound

* Entangled animals previously tagged as pups with Monel tags. Monel tags were left on the seals and numbers recorded

APPENDIX E

Tag numbers and measurements of northern fur seal pups tagged on San Miguel Island, California, in 1993.

Appendix Table E-1.-- Northern fur seal pups double-tagged with pink plastic roto tags at Adams Cove, San Miguel Island, California, 22 September 1993.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A1901	M	9.2	76.0	53.0
A1902	F	10.1	75.0	56.0
A1903	F	9.2	76.0	54.0
A1904	M	11.2	80.0	56.0
A1905	F	10.2	76.0	54.5
A1906	F	9.2	72.5	52.0
A1907	M	8.4	79.0	49.0
A1908	M	6.6	71.0	47.0
A1909	M	10.4	82.0	56.5
A1910	F	9.0	78.0	54.0
A1911	M	8.4	74.0	54.0
A1912	M	8.8	76.0	53.0
A1913	M	9.4	81.0	56.5
A1914	F	6.8	71.0	46.5
A1915	M	10.8	80.0	58.0
A1916	F	6.4	67.0	47.5
A1917	M	9.7	81.0	57.5
A1918	F	9.8	81.0	51.5
A1919	F	9.4	75.5	50.5
A1920	F	7.9	72.0	47.0
A1921	M	10.8	81.0	58.0
A1922	M	10.7	77.0	59.5
A1923	F	8.1	73.0	48.5
A1924	M	6.2	72.0	42.5
A1925	F	10.4	74.0	53.0
A1926	M	13.2	83.0	60.0
A1927	M	10.0	80.0	53.0
A1928	F	8.4	72.0	53.5
A1929	F	6.8	73.0	47.0
A1930	M	7.8	75.0	49.0
A1931	M	9.8	80.0	55.0
A1932	F	6.4	73.0	47.0
A1933	F	8.6	77.0	52.5
A1934	F	11.0	77.0	58.5
A1935	F	14.8	85.0	66.0
A1936	M	8.3	72.0	52.0
A1937	M	7.0	75.5	49.0
A1938	F	9.4	81.5	55.0
A1939	M	6.2	71.0	46.0
A1940	F	6.2	73.0	44.0
A1941	F	9.3	76.0	57.5
A1942	M	7.6	74.0	48.5

Appendix Table E-1.-- Continued.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A1944	M	9.0	80.0	54.0
A1945	M	9.4	78.0	54.5
A1946	M	12.0	82.0	61.0
A1947	M	13.4	86.5	61.5
A1948	F	6.8	72.0	49.0
A1949	M	10.4	78.0	53.0
A1950	M	10.8	83.0	55.5
A1951	M	12.1	82.0	59.5
A1952	M	9.6	81.0	53.0
A1953	M	9.0	78.0	50.0
A1954	F	9.0	74.0	51.0
A1955	M	10.2	80.5	53.5
A1956	F	10.6	81.0	54.5
A1957	F	7.8	71.0	51.5
A1958	F	10.0	73.0	53.0
A1959	M	14.2	84.0	59.0
A1960	M	8.0	78.0	52.0
A1961	F	11.2	82.0	57.0
A1962	F	6.6	76.0	46.0
A1963	F	7.3	72.0	51.0
A1964	F	10.6	85.0	57.0
A1965	F	9.6	78.0	53.0
A1966	M	7.4	76.0	52.0
A1967	M	13.0	85.0	59.0
A1968	M	9.0	78.0	52.0
A1969	M	11.6	84.0	58.5
A1970	M	11.8	85.0	57.0
A1971	F	10.2	80.0	54.0
A1972	F	12.4	82.0	56.5
A1973	F	9.3	73.0	53.5
A1974	F	10.2	77.0	52.0
A1975	M	13.8	81.0	58.5
A1976	F	10.0	81.0	51.5
A1977	M	8.4	77.0	49.0
A1978	M	7.2	76.0	45.0
A1979	M	10.0	79.0	53.0
A1980	M	7.2	76.0	49.0
A1981	F	8.8	77.0	52.0
A1982	F	7.2	72.0	50.0
A1983	F	10.6	82.0	56.5
A1984	M	7.4	75.0	50.0
A1985	M	8.2	76.0	46.5
A1986	M	13.2	82.0	57.0
A1987	M	7.2	77.0	44.0
A1988	F	8.4	80.0	48.5
A1989	F	7.6	77.0	47.0

Appendix Table E-1.-- Continued.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A1990	M	10.4	76.0	53.5
A1991	F	9.9	82.0	51.5
A1992	F	10.8	80.0	57.0
A1993	M	11.0	81.0	53.5
A1994	M	10.5	78.0	57.0
A1995	F	11.2	80.0	57.5
A1996	F	7.4	76.0	49.0
A1997	M	7.8	77.0	44.5
A1998	F	9.2	78.0	55.0
A1999	M	10.4	84.0	58.5
A2000	M	12.6	80.0	59.0
A2001	M	7.0	72.0	49.0
A2002	M	12.4	78.0	58.5
A2003	M	9.0	76.0	52.5
A2004	F	11.2	78.0	57.0
A2005	F	7.6	78.0	51.5
A2006	F	9.8	76.0	53.0
A2007	M	7.6	73.0	49.5
A2008	F	11.6	79.0	57.0
A2009	M	11.2	80.0	54.0
A2010	M	9.8	81.0	54.0
A2011	F	8.6	78.5	51.0
A2012	M	9.6	77.0	54.0
A2013	F	8.2	70.5	54.0
A2014	F	7.4	71.0	49.0
A2015	M	12.0	83.5	59.0
A2016	M	8.0	78.5	49.0
A2017	F	10.5	78.0	57.0
A2018	F	12.6	83.0	59.0
A2019	M	9.8	78.0	54.0
A2020	F	8.2	74.0	49.0
A2021	F	8.0	73.0	48.0
A2022	M	10.0	79.0	55.5
A2023	F	7.9	75.0	49.5
A2024	F	9.6	80.0	58.0
A2025	F	11.6	76.0	59.0
A2026	F	8.2	75.5	52.0
A2027	F	6.8	73.0	42.0
A2028	M	11.0	79.0	55.0
A2029	F	11.0	80.0	54.0
A2030	F	9.8	76.0	54.0
A2031	F	8.2	75.0	48.5
A2032	F	11.0	78.0	58.5
A2033	F	9.4	77.5	51.0
A2034	F	9.0	73.0	54.0
A2035	F	9.2	76.0	50.5

Appendix Table E-1.-- Continued.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A2036	M	10.4	77.0	57.5
A2037	M	8.0	76.0	51.5
A2038	M	8.1	76.0	49.0
A2039	F	10.5	78.5	55.5
A2040	M	10.4	81.0	54.5
A2041	F	8.8	75.0	49.5
A2042	F	9.2	76.0	51.5
A2043	F	9.2	79.0	53.5
A2044	F	9.0	75.0	54.0
A2045	M	12.0	87.0	60.5

Appendix Table E-2.-- Northern fur seal pups double-tagged with pink plastic roto tags at Adams Cove, San Miguel Island, California, 22 October 1993.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A1801	M	15.5	80.0	64.0
A1802	M	16.1	82.0	65.5
A1803	M	12.8	78.0	58.0
A1804	M	16.6	78.0	63.0
A1805	M	13.5	84.0	59.0
A1806	F	10.9	75.0	58.0
A1807	M	9.8	71.0	54.0
A1808	F	11.4	80.0	58.0
A1809	F	13.3	75.0	62.0
A1810	M	15.6	81.0	70.0
A1811	M	12.2	78.0	64.0
A1812	M	14.0	81.0	62.0
A1813	F	13.4	80.0	59.0
A1814	M	13.2	75.0	63.0
A1815	M	13.2	76.0	60.0
A1816	M	14.0	79.0	63.0
A1817	F	7.3	69.0	52.0
A1818	M	8.0	69.0	51.0
A1819	M	11.2	76.0	57.0
A1820	F	9.4	70.0	59.0
A1821	M	9.8	70.0	54.0
A1822	F	11.5	72.0	59.0
A1823	M	10.6	78.0	55.0
A1824	F	14.0	78.0	65.0
A1825	M	13.4	84.0	63.0
A1826	F	13.7	80.0	63.0
A1827	M	16.2	84.0	68.0
A1828	F	7.8	70.0	49.0
A1829	F	13.5	80.0	63.0
A1830	M	9.6	76.0	57.0
A1831	F	9.2	71.0	53.0
A1832	M	8.6	72.0	51.0
A1833	M	14.2	80.0	66.0
A1834	F	12.2	74.0	61.0
A1835	M	16.1	88.0	66.0
A1836	F	10.8	74.0	61.0
A1837	M	13.6	82.0	61.0
A1838	M	15.4	79.0	66.0
A1839	F	11.7	79.0	61.0
A1840	F	10.6	74.0	56.0
A1841	F	13.2	79.0	64.0
A1842	M	12.2	80.0	61.0
A1843	M	10.4	76.0	54.0
A1844	M	14.3	82.0	61.0

Appendix Table E-2.-- Continued.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A1845	F	10.0	75.0	54.0
A1846	F	9.8	73.0	53.0
A1847	F	6.8	71.0	45.0
A1848	F	13.2	75.0	66.0
A1849	F	9.4	71.0	55.0
A1850	M	11.1	75.0	55.0
A1851	F	14.0	79.0	63.0
A1852	F	16.8	83.0	69.0
A1853	F	8.7	74.0	64.5
A1854	F	14.0	80.5	62.0
A1855	M	14.0	80.5	58.0
A1856	F	8.8	71.5	50.0
A1857	F	11.5	76.0	58.0
A1858	M	12.0	75.0	57.0
A1859	F	10.5	73.0	53.0
A1860	M	11.4	79.5	55.0
A1861	F	13.2	80.0	56.0
A1862	F	10.5	75.5	55.0
A1863	F	9.8	75.0	53.0
A1864	M	13.6	80.5	60.5
A1865	M	11.8	79.0	57.5
A1866	M	13.4	78.0	57.5
A1867	M	14.5	81.5	59.0
A1868	M	15.0	78.5	60.0
A1869	F	14.5	78.5	59.5
A1870	M	9.8	73.5	52.0
A1871	M	12.4	84.5	59.0
A1872	M	16.8	85.0	66.5
A1873	M	9.5	76.5	52.0
A1874	F	11.2	76.0	56.0
A1875	M	8.9	74.0	50.5
A1876	F	11.2	75.0	59.0
A1877	M	14.0	79.5	67.0
A1878	M	14.0	80.0	61.0
A1879	F	12.0	77.0	60.0
A1880	F	10.3	77.0	55.0
A1881	M	13.0	83.0	55.5
A1882	F	13.2	76.0	59.5
A1883	M	8.8	76.0	54.0
A1884	F	10.0	71.5	55.5
A1885	F	12.5	79.0	58.0
A1886	M	14.9	81.0	59.0
A1887	F	12.0	81.5	57.0
A1888	M	9.4	73.0	53.0
A1889	M	12.3	76.5	58.5
A1890	M	11.4	73.5	59.0

Appendix Table E-2.-- Continued.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A1891	M	14.4	80.0	61.0
A1892	M	9.5	71.5	51.0
A1893	F	11.2	76.5	56.0
A1894	M	14.8	82.0	63.5
A1895	F	11.8	76.0	56.0
A1896	F	9.1	74.0	53.0
A1897	M	11.7	79.5	55.0
A1898	F	12.0	76.0	55.0
A1899	M	14.3	78.0	65.5
A1900	F	8.3	74.0	50.0
A2046	F	11.5	79.0	54.0
A2047	M	11.9	77.0	62.0
A2048	M	19.8	87.0	71.0
A2049	F	12.8	81.0	61.0
A2050	M	11.2	80.0	58.5
A2051	M	12.6	81.0	59.5
A2052	F	11.8	81.0	54.5
A2053	M	9.5	74.0	50.5
A2054	F	9.9	75.0	51.5
A2055	F	10.8	78.0	54.0
A2056	F	8.4	75.0	46.0
A2057	M	10.8	78.0	54.0
A2058	M	11.2	82.0	52.0
A2059	M	10.0	75.5	57.0
A2060	F	12.8	86.0	57.0
A2061	M	13.9	83.0	61.0
A2062	M	12.6	85.0	54.5
A2063	M	10.4	80.0	51.0
A2064	F	10.2	81.0	52.5
A2065	M	15.6	86.0	64.5
A2066	F	10.5	76.0	59.0
A2067	F	15.4	89.0	59.0
A2068	F	11.2	79.0	53.0
A2069	M	9.6	78.0	52.5
A2070	F	7.4	70.0	46.0
A2071	F	12.2	79.0	55.0
A2072	M	17.0	88.0	63.0
A2073	M	12.6	84.0	54.0
A2074	M	15.4	82.0	60.0
A2075	F	7.8	76.0	47.5
A2076	M	12.6	81.0	56.5
A2077	M	13.0	83.0	55.5
A2078	M	16.4	84.0	65.5
A2079	M	11.8	79.0	54.0
A2080	M	14.6	82.0	58.5
A2081	F	11.8	79.0	52.5

Appendix Table E-2.-- Continued.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A2082	F	19.0	86.0	65.0
A2083	F	13.3	80.0	59.5
A2084	F	15.4	81.0	60.0
A2085	F	14.2	82.0	59.0
A2086	F	13.2	83.0	57.5
A2087	F	9.0	74.0	45.5
A2088	M	11.2	86.0	51.5
A2089	M	14.6	80.0	59.0
A2090	F	11.5	79.0	54.5

Appendix Table E-3.-- Northern fur seal pups double-tagged with white roto tags at Castle Rock, San Miguel Island, California, 21 September 1993.

Tag number	Sex	Weight (kg)	Length (cm)	Girth (cm)
A91	M	10.6	82.0	57.0
A92	F	8.4	73.0	51.0
A93	F	8.8	83.0	50.0
A94	F	10.8	88.0	55.0
A95	M	10.5	78.0	54.0
A96	M	8.9	77.0	52.0
A97	F	6.4	71.0	46.0
A98	F	9.0	77.0	51.0
A99	M	9.4	83.0	50.0

APPENDIX F

Scientific staff engaged in northern fur seal research in 1993.

National Marine Mammal Laboratory (NMML)
Howard W. Braham, Director
Robert V. Miller, Deputy Director
Thomas R. Loughlin, Leader, Alaska Ecosystem Program

Name	Affiliation	Assignment
Employees		
George Antonelis	NMML	Project Leader
Jason Baker	NMML	Population Dynamics
Robert DeLong	NMML	Population Assessment
Charles Fowler	NMML	Population Dynamics
Roger Gentry	NMML	Behavioral Studies
James Lerczak	NMML	Population Assessment
Thomas Loughlin	NMML	Population Assessment
Sharon Melin	NMML	Population Assessment
Rolf Ream	NMML	Population Assessment
Bruce Robson	NMML	Population Assessment
Elizabeth Sinclair	NMML	Foraging Dynamics
Rod Towell	NMML	Population Dynamics
Anne York	NMML	Population Dynamics
Cooperators		
Denise Bradley	WPI	Pup Disease and Mortality
David Cormany	NMFSJ	Resource Management
Steve Insley	UCD	Behavioral Studies
Shinjiro Kitani	NRIFS	Reproduction Studies
Masashi Kiyota	NRIFS	Reproduction Studies
Philip Lekamof	CSG	Population Assessment
Tracy Schall	NMFSD	Population Assessment
Terry Spraker	WPI	Pup Disease and Mortality
Michael Williams	UAF	Population Assessment
Steve Zimmerman	NMFSJ	Resource Management

Affiliation Code

CSG - City of St. George, St. George Island, Alaska
NMML - National Marine Mammal Laboratory, Seattle, Washington
NMFSD - National Marine Fisheries Service, Dutch Harbor, Alaska
NMFSJ - National Marine Fisheries Service Regional Office, Juneau, Alaska
NRIFS - National Research Institute of Far Seas Fisheries, Shimizu, Japan
UAF - University of Alaska, Fairbanks, Alaska
UCD - University of California, Davis, California
WPI - Wildlife Pathology International, Boulder, Colorado

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